Approaches to the regulation of fishing effort

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FOOD
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AGRICULTURE
ORGANIZATION
OF THE
UNITED NATIONS

Approaches to the regulation of fishing effort

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PREPARATION OF THIS PAPER

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Abstract

The problems of controlling fishing effort are reviewed. Any method should satisfy certain criteria - maintaining the productivity of the resource, economic performance and equity (or social needs). The methods of achieving these objectives are reviewed; they include the setting of catch limits, direct control of fleet capacity (e.g. restricting the number of fishing units), indirect measures (mesh size, closed areas), financial measures and the establishment of property rights to fishing areas or quantities of fish. The advantages and disadvantages of each approach are discussed in the light of the established criteria and appropriate techniques are given for six specific types of fisheries.

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1. INTRODUCTION

Clearly, the most important question to pose in a study devoted to methods of controlling fishing effort is: why should fishery managers seek to control fishing effort at all?

Certainly the control of fishing effort is not a new phenomenon. Pearse (1980) indicates that trawling in France was controlled as early as the 17th century and most industrial fishing nations have a history of attempts at effort control. Depending on one's preference, the reasons for controlling fishing effort may be sought either in theory or practice or both.

Michael Graham in 1949 was one of the first people to examine both the empirical evidence and the underlying theoretical reasons for the need to control fishing effort. Since Graham many others, but most noticeably Hardin (1968), have considered the necessity for controlling access to commonly owned property.

The basic development of the economic ideas is due to Gordon (1954). Gordon's analysis depends on simple economic theory and predicts, in effect, that when a fishery is uncontrolled the following pattern of activity occurs. Initially, as the fishery develops, fishermen experience high catch rates on the abundant resources and make high profits. This attracts other fishermen into the industry and encourages those already there to increase their investment. Increasing fishing pressure then reduces the fish stock and increases competition amongst the fishermen for the dwindling resources. This reduces catch rates and hence profits to a level where the earnings merely cover the costs of the labour and capital employed, or, in the jargon of economics, to a level where the economic rent (value of landings minus costs of catching and delivering the fish) is completely dissipated.

This "open-access" result contrasts markedly from that which occurs where a fishery is the property of a sole owner (Scott, 1955). In this case the ability of the sole owner to collect a rent creates a significant incentive for the fish stocks to be husbanded for future as well as current use. It also leads to harvest of the resource at much lower cost.

Theoretically the steady state of an open-access fishery may or may not be at a level where the fish stock is below the level where it produces its Maximum Sustainable Yield (MSY). However, it is often the case in high value fish resources that this bio-economic equilibrium occurs at an effort level well above the MSY level, at a point where the resource is severely depleted.

This simple picture of the bio-economic equilibrium should not be viewed as providing an exact empirical description of events in a fishery. In a particular situation a number of complicating factors alter the details, if not the general picture of the open access fishery. Most importantly it should be recognized that both the fish stock and the fishery based on it will be subject to a number of exogenous factors. Those factors will tend to shift and alter the yield, revenue and cost curves, and a true deterministic equilibrium does not exist; indeed the concept of an equilibrium is best viewed in the real and stochastic world as a metaphor in which the long-term average behaviour of the system is described.

There are a number of economic disadvantages to a bio-economic equilibrium of this sort. The first and most obvious is that the fishing industry will be operating at a level of excessive costs and hence society will be failing to obtain the appropriate benefits from its fishery resource. An additional implication of Gordon's analysis has been highlighted by Clark (1977). Clark notes that as the industry tends towards the equilibrium the more efficient fishermen with high opportunity costs, i.e., the ability and opportunity to work elsewhere, will leave the industry. Those remaining will be the less efficient, who have little opportunity to work elsewhere. Doucet (1984) documents this problem for fishermen in the Bay of Fundy, and other examples may be found in a number of isolated fishing communities.

Apart from these economic disadvantages, there can also be major problems of conservation. In certain pelagic fisheries there is a tendency for catch rates to remain at a high level even though the fish stock is being reduced. The consequences of this increasing "catchability" with decreasing stock size are that severe over-exploitation of the fish stock may occur. Dramatic cases in point are the fisheries for the anchoveta off Peru and herring in the North Atlantic (Saetersdal, 1980; Ulltang, 1977; Butterworth, 1983; Troadec, Clark and Gulland, 1980).

It should be emphasized that conservation problems are not restricted to pelagic species, for the phenomenon of over-fishing, in a biological sense is ubiquitous.

For most species major declines in productivity have been produced when a reduction in the spawning stock has been associated with lower than normal recruitment. It is inappropriate in this document to deal with the stock and recuitment problem in any detail. Nevertheless, certain problems are worth highlighting. Firstly recruitment is highly variable (Hennemuth, Brown and Palmer, 1980) and although the variability differs significantly between groups (Beddington and Cooke, 1983) for most stocks it is largely unpredictable. The various models of stock-recruitment relationships from Ricker (1958) through to Shepherd (1982) add understanding of the possible patterns of recruitment, but are useless for predictive purposes (Garrod, 1983). The important point is that as stocks have been reduced there is a tendency for recruitment to decrease, although this decrease may be small for moderate levels of stock reduction. However, it is extremely difficult, due to the nature of fisheries' data, to fix on some stock' level where significant change may be expected. Hence arbitrary assignment of some target escapement level (below which the stock should never be reduced) appears to be the most appropriate method of ensuring against poor recruitment.

The above ideas apply to separate stocks, but in some cases the productivity of whole communities can be reduced; for example, where a trawl fishery is capable of catching a whole selection of species from the fish community. Examples of such fisheries occur in the Gulf of Thailand, in the waters off Indonesia and Malaysia (Pauly, 1979a; Majid, 1984).

These considerations appear to suggest that the major problem is one of ensuring that the biological productivity of the resource remains high. However, it should be emphasized that a simple set of regulations aimed at ensuring the conservation of the biological stocks, even if successful, will not solve all the economic or social problems. In such situations, although catastrophic declines are now less likely to occur in the resource, nevertheless the open access character of the fishery means that the industry will tend to develop to a level where economic rent is dissipated and a catch is taken at a level of investment where the average level of profit in the industry is low.

In some sense this paper can be considered as a warning. For a number of the developed countries, many of the problems outlined above have already occurred. There is considerable over-capacity in the fishing industry, in the sense that the fishing power of the fleets far exceeds that required to take the typical catch levels. Furthermore many fish stocks are over-exploited, in the sense that their capacity to produce a sustainable yield has been substantially reduced.

One of the mistakes made in certain countries has been to treat these problems of the fishing industry with subsidies. Originally this was thought to be a simple and effective way of alleviating hardship in low income communities. It was not recognized that such subsidies have an unfortunate disturbing effect on the position of the bio-economic equilibrium. When the industry is benefitting from subsidies, the equilibrium occurs at greater levels of economic inefficiency, as subsidies often mean that capacity stays within rather than leaves the industry (Brochmann, 1984a).

It is sometimes claimed that, prior to the almost universal adoption of exclusive economic zones (EEZs), the pre-law of the sea conditions of open access were responsible for many of the problems of over-exploited fish stocks and over-capitalized industries. To some extent this is true, but it cannot be emphasized too strongly that such threats can also occur within individual nations' EEZs. This matter is reconsidered below, but it is useful to highlight one problem in this Introduction.

In the development of a fishery there is a major problem caused by the speed at which fishing capacity can increase. In the past this increase in capacity has often out-stripped the ability of the regulating authority to institute controls and the ability of the scientific community to assess the effect on the resource. Classic examples abound, but the anchovy fishery in Peru is probably the most well known (Glantz and Thompson, 1981).

With the adoption of EEZs, many countries have sought to develop their fishing industry with the help of bilateral assistance agencies, international development banks and other agencies. In principle such assistance is welcome, and properly applied, can be highly successful. Nevertheless, it should be noted that such programmes of development can aggravate the tendency for investment to outstrip monitoring and control capabilities. These matters are considered in more detail below.

A final problem of the bio-economic equilibrium, which occurs in the absence of regulation, concerns the competition between different sectors of the fishing community. In a situation of open access it can often be the case that capital-intensive vessels are at a competitive advantage; albeit that the overall level of economic rent is zero. With access controlled to the fishery, less capital-intensive vessels may well be more cost effective (Tillion, 1984).

Such problems are posed in dramatic form in the competition between industrial fisheries operating offshore with trawlers and artisanal fisheries restricted to the narrow coastal strip. These conflicts have resulted in dramatic fishery regulations: the banning of trawling in Indonesian waters is a recent example (Sardjono, 1980).

Having dealt with the whole set of problems that occur if fisheries are unregulated, it is clearly reasonable to ask: what are the solutions? A number of techniques of controlling fishing effort have been attempted, with varying success. In the remaining sections of this report these various techniques are considered and assessed. However, in order to assess the techniques, it is necessary to consider first the sorts of criteria that must be satisfied. This is dealt with in the next section.

Having reviewed the various techniques, and having dealt with the problem of assessment of the success, or failure, of different methods, in the final section we analyse the opportunities for controlling fishing effort in several major types of fishery.

2. CRITERIA FOR REGULATION

2.1 The role of criteria

The design of any fishery management programme is greatly aided by a clear understanding of the goals for that programme. In some countries these goals are clearly spelled out in advance as well as the criteria by which management alternatives will be judged. In other countries, while each person involved in the discussions may have individual perceptions of underlying goals, public discussion is related only to the strategies used to approach the various goals. Whether objectives are explicitly stated or implicit in policy discussions, they are often large in number, diverse, conflicting, and require consideration of trade-offs. The precise objectives to be used in a management discussion will vary from place to place and over time, and will shift as external circumstances change. Nonetheless, five broadly defined criteria are often identified: conservation, economic performance, social values (especially equity), administrative feasibility, and political acceptability. Since this document discusses regulation of fishing mortality, with respect to those criteria, each will be briefly discussed.

2.2 Conservation

The most commonly recognized reason for the regulation of fishing effort is the need for conservation of fish stocks. Indeed this was one of the main reasons for the call for a thorough re-examination of the Law of the Sea (LOS) a decade or so ago.

The basic criterion for conservation of a stock is that it should be able to provide a sustainable yield. Stocks when they have been reduced substantially have a tendency to produce failures in recruitment which, for a time, reduce their ability to produce a sustainable yield. Although well recognized, this presents a significant problem, as recruitment in many stocks is highly variable and the level of reduction in stock size, at which declines in recruitment may be expected, cannot readily be ascertained.

This problem is exacerbated because data accumulate typically on a very slow time scale and the techniques for analysing stocks such as Virtual Population Analysis (VPA) are unable to predict successfully into the future (Gulland, 1977; Pope, 1979; Pope and Shepherd, 1982).

Often data on recruitment and stock size obtained by VPA do not show a sufficient degree of evidence to justify reduction in the amount of fishing until the process is well advanced. Accordingly there has been a tendency for exploitation to continue until the stock is severely depleted and a major reduction, or a complete closure of the fishery has to be introduced. Typical examples of such fisheries abound: the North Sea herring, the Atlanto-Scandian herring, the anchoveta, the Californian sardine, etc. The history of many such fisheries is reviewed by Saetersdal (1980).

In situations where recruitment has shown a major decline, insufficient is known about the processes involved for scientists to be able to predict the recovery rate when fishing is reduced or stopped. Some species appear to remain at low levels for long periods in the absence of exploitation. Well known examples are the Californian sardine (MacCall, 1980), the herring of the Georges Bank (Anthony and Waring, 1980), and the sardine off Japan (Kondo, 1980). A typical case in point is the herring of the North Sea (ICES, 1982). The recovery of fish stocks in the North Atlantic following the 1914-18 and 1939-45 wars is often cited as a major predictable recovery of fish stocks. However, this recovery was mainly from a situation of growth over-fishing not of recruitment failure.

Where a species remains at a low level following over-exploitation, correlated changes in the abundance of other species often occur. Most notable are the inter-correlated oscillations in abundance of the anchovy, sardine and scomber systems off Peru and Chile, California and South-West Africa. Ecological theory would predict such replacements by similar species, but the nature of fisheries' data precludes a quantification of such phenomena. Daan (1980) provides a review of the main examples and argues that 'replacement' is seldom exact or simple.

While the replacement species could turn out to have higher unit value, there is no way of predicting exactly which species if any will benefit from the reduction of a target species. Hence, in general, there is a tendency to view all recruitment collapses as phenomena to be avoided. Indeed even where recovery occurs following a cessation or reduction in fishing, the economic disruption to both the fishing industry and the marketing sectors dependent on it can be severe (MacSween, 1984).

A further complication caused by changes in the community structure and fishing pattern has been considered theoretically (May et al., 1979; Andersen and Ursin, 1977). This occurs when fishing is first concentrated on a predator species, then, as the predators are reduced, shifts attention to an increased prey. Sustainable yields of the predators are thus threatened both from potential recruitment collapse and from a reduction in their food supply.

Such considerations have played an important role in the framing of legislation where marine mammals are important as higher predators. The articles of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) explicitly tie the rate of exploitation of the main prey species, the krill, to the ability of the predators to feed adequately on the krill resource. Such considerations are also recognized in the management of the Californian anchovy population, where the management plan sets aside a specific "forage reserve" for predator consumption (McInnis, 1984).

In tropical multi-species trawl fisheries, a different problem arises. Here, there is a necessity for regulating the total fishing effort applied to the community, in order that changes in species composition do not occur which are either irreversible or economically detrimental.

In Thailand, Indonesia and Malaysia there has been a tendency for an increase in the proportion of trash fish to occur as the fishery progresses. In effect the fishery is producing a relatively constant yield from the community, but the underlying species composition of the community is altering with a tendency towards smaller, and generally less valuable specimens.

Although relatively little is known about the dynamic interactions of these fish communities (see Pauly, 1981), there is a possibility for altering the pattern of fishing mortality imposed, in order that the sort of species changes that have been observed do not occur, or occur to a lesser extent.

In part this tendency comes from the phenomena that occur in all exploited fish stocks where the age composition of the catch moves towards younger fish as fishing progresses. However, in these tropical systems this tendency is also accompanied by a move towards more abundant small species. Such species typically have high rates of mortality and recruitment and are capable of replacing slower growing, but initially more abundant species. A variety of interpretations along these simple ecological lines have been proposed (e.g., Gulland, 1977; Pauly, 1979a; Caddy, 1984a). Such explanations are little more than metaphors, but do highlight the problems of such fisheries.

There is a need in these communities to consider what the appropriate goal is for a fishery of this sort. This could be framed in biological terms; for example, a maximum sustainable yield of fish greater than a certain size. This might well also produce a high economic yield; however, there are complications, e.g., shrimp are small and of high value.

Clearly, there are a number of inter-related problems in establishing conservation criteria for stocks or communities. Most appear to depend on the ability of the resource to continue to provide yields. Where regulations fail to restrict fishing, so that this ability is reduced for a substantial period of time, they can be thought to have failed. In effect this implies that the biological criteria for conservation can be encapsulated in the simple idea that changes in the community or target species abundance should be reversible on some reasonable time scale. Interestingly, wording of this sort is already part of the CCALMR text.

2.3 Economic performance

When fisheries are unregulated, the approach to the bio-economic equilibrium is accompanied by increasing economic inefficiency. As a fishery develops there may be an initial tendency for costs to decline as improved knowledge about the location of the more abundant resources improves efficiency. However, as more fishing effort is attracted into the fishery and the stocks are reduced, costs tend to rise and revenues per unit effort tend to decline. Such changes tend to occur as the best or nearest fishing grounds are over-exploited and less attractive areas have to be fished.

The bio-economic equilibrium is reached in theory when the lack of profits discourages further entry. Often in practice a variety of factors, including a lack of information about the consequences of entry, result in average costs actually exceeding average revenues. The effect on income levels in such fisheries is correspondingly severe. In many cases, where particular skills are acquired by the fishermen and vessels are of a special type, withdrawal from the fishery is difficult. Accordingly, there is a tendency for heavily-exploited open-access fisheries to have a fishing fleet composed of relatively old vessels crewed by older fishermen.

While the initial motivation for implementation of fishery regulations may be conservation, often an important motive is concerned with the low incomes prevalent in the fishery. A major set of criteria for fishery regulation is therefore concerned with improving the economic performance of the fishery. Clearly this can be done by increasing the average economic return either by increasing average revenues or by lowering average costs.

Generating the maximum economic return from fisheries is rarely the main objective in fishery management (Bain, 1984). However, careful attention to both the costs and benefits due to regulation is required if fisheries are to be a source of value, and not a burden, to a country. This is true, both in terms of the impact on profits and losses in the fishing industry and in terms of public revenues generated and public costs caused by regulation due to increased data collection, research, administration and enforcement.

A related issue of great concern in many countries is whether changes in fishery regulations lead to an increase in foreign exchange (perhaps by enhancing the export of fish products) or are a drain on such funds.

Politicians and public administrators seldom refer to the concept of economic efficiency. Instead they express concern for high rates of unemployment, bankruptcies, and stagnant or declining income levels. Such economic consequences often result from increasing costs such as fuel prices and interest rates, slack demand for fish products as well as declining fish availability. Since fishermen enter a fishery much more readily when prices are rising or the fish resource is increasingly plentiful, than they leave the fishery when conditions deteriorate, policies may be favoured which reduce the variability, in the amount of fish harvested. In addition, spokesmen for the fishing industry stress the need for an even and predictable supply of fish to maintain ports, cold storage and freezing operations, transportation facilities, and processing and distribution activities as well as minimum numbers of individuals in various gear groups (MacSween, 1984).

To secure the best economic value from any level of fish harvested, emphasis must be placed on the quality of fish as they are caught or as they reach the consumer. Thus regulations should be set to encourage catch at the time of year when quality reaches an acceptable standard and to move that catch into processing and marketing channels in ways which will maintain quality.

Marketing considerations also require attention to acceptable sizes of fish. Usually this means landing fish at sizes such that processing is economical, as when a minimum size is needed to produce good fillets. However, it can also mean permitting harvest at several sizes to fill various market niches. Just as cattle satisfy demands for both veal and beef, so do some consumers of fish have varying preferences. An extreme example is when harvest of herring for its roe content yields a food fish with little appeal, while harvest for best food use would leave the roe market unsatisfied.

2.4 Social values

Where movement toward open-access equilibrium reduces the average profitability of a fishery, some fishermen are affected more than others. Indeed, some fishermen may be so adaptable to the new circumstances that they earn good profits in spite of the overall poor state of the industry. In certain cases, faced with impending bankruptcy, attempts may be made to increase catches by operating for longer hours or in previously unfished areas. All such effects will tend to reduce further the fish resource, with a corresponding impact on the rest of the fleet.

Such effects can lead to illwill and, at times, violence by some fishermen toward other fishermen. Many fishery regulations which originate from fishermen themselves are often designed to reduce social turmoil among a group of fishermen or between groups of fishermen.

The most difficult task for fishery managers is to choose among alternative regulations which make one group of fishermen better off and another group worse off. When one of the groups is considered to be "our fishermen" and the other group to be "their fishermen", the choice is fairly predictable.

However, there are many difficult choices when one group is explicitly to be favoured. Quite often, preferred treatment can only be inferred from actions taken since it is not good politics to openly state favouritism. Some of the cases in which explicit preferences have been shown are as follows. In some fisheries, full-time fishermen are treated specially relative to part-timers. Fishermen harvesting for their personal food use have a higher priority than commercial fishermen with both groups given an advantage relative to recreational fishermen (this order being slightly different in some countries). The status of near-shore fishermen relative to distant-water fishermen is a difficult issue in many nations. Preference by vessel size is common and is associated with difficult choices between artisanal fishermen and industrial fleets. Fishermen operating on their own vessels sometimes are given an advantage over fishermen operating on vessels owned by corporations (perhaps processing firms). Treatment is also different for fishermen relying on one or a few fisheries and highly diversified operators; preference is at times given according to the fishermen's homeport or residence and various ethnic groups are treated differently.

Even when one group is given a higher status in the eyes of the government than another group, there is still the question of how much to favour that group. If you place the interest of the artisanal fisherman ahead of the industrial fleet, must you completely satisfy the artisanal group before providing any opportunity to the industrial sector?

Most public policies will implicitly give some advantage to one group over another. For example, a decision to support the development of fisheries may work against artisanal fishermen. A failure to identify such implications may lead to equity consequences which the management authority may greatly regret.

Whether some groups are treated with special consideration or all groups have equal standing, management decisions must withstand scrutiny with respect to concepts of fair and equitable treatment of various fishermen. However, equity is a most difficult concept subject to diverse interpretations. For example, an equitable share of the catch may refer to one given year or an average over a series of years. Equity might also refer to distribution of income, access conditions (perhaps with respect to season, gear restrictions, or area) or the government processes leading to consideration of alternatives. The problem of which concept of equity to actually use may be most difficult in practice. For example, recreational fishermen may complain about the unfair share of a particular species caught by commercial fishermen, while the commercial fishermen complain about the unfairness of recreational fishermen having a longer season.

While equity is an extremely important social consideration to be used in assessing fishery regulations, it is not the only one. For example, fishermen often complain that their individual occupational objectives are inadequately considered when regulations are set. Many fishermen chose their way of life because they wished to be independent while living an outdoor life full of challenge, with a lack of regimentation, full of a sense of identity, and proud of their occupation (Thomson, 1984). Further, many of them argue that their heritage does not allow any other self-image. They also want a great deal of flexibility in choosing target species, size and type of vessel to operate, gear to use, what time of year (week, day, and time of day) to fish, and the area in which they will fish. Such flexibility implies to them both ease of entry and exit from a specific fishery.

While the social values just described may imply minimal government involvement, other concerns suggest some kind of intervention. As the number of fishermen operating in a given fishery increases, greater attention is needed to provide for orderly fishing and reduction in user group conflicts. The public may be concerned with the unemployment rate among fishermen or in particular fishing communities. There may also be concern about the dislocation of particular social groups which might occur if fish stocks available to a remote fishing community were depleted or pre-empted by a distant-water fishing group.

2.5 Administrative feasibility, enforcement and costs

Clearly regulations need to be administratively feasible, in the sense that their operation involves suitable choices of timing, monitoring and control. However, the most important additional criteria by which regulations may be judged concern the cost and feasibility of their enforcement. There are two main areas of concern.

The first involves the extent that it is necessary to monitor the activity of the fishery. Different regulations demand different types and degrees of monitoring and data collection. The second concerns the fishermen's understanding of the regulation and their attitude to it. If regulations are complex, difficult to understand and are perceived by the fishermen to be against their interests, then enforcement will be costly.

2.6 Political acceptability

Perhaps the most important question to be addressed by any government before adopting or significantly expanding the use of a current regulatory approach is "Can we afford it?" The costs involved are not just the purely financial considerations, already discussed, but also include the erosion of a limited political base. Expanding public regulations can lead to criticism and a decrease in political power. However, so can a failure to take action in the face of declining catches or conflicts between different groups of fishermen.

Recognition of political costs is one of several factors which cause most governments to adopt incremental approaches to resource management. Unless a strong mandate is found to justify radical approaches, regulations are commonly adopted which are modest changes in previous fishery regulations or, at a minimum, are clearly analogous to resource regulations used elsewhere in the country. For example, a country which imposes closures on some fish stocks can place a time closure on a previously unregulated fishery with less political criticism than a country which has never used seasonal closure to manage any fish or wildlife resource.

3. TECHNIQUES FOR REGULATING FISHING MORTALITY

3.1 Catch limits

Recently the standard procedure for regulating fishing effort in most of the developed world has been by catch limits (TACs). There are a number of advantages and disadvantages in setting catch limits and in regulating fishing effort by these means. The most serious disadvantage, which was touched on in the Introduction, is that catch limits in isolation are, even if successful, only capable of solving problems of resource conservation. Unless they are allocated in some way, either between national groups, or within a nation's fishing community the problems of over-capitalization remain.

In this section we consider firstly the relevant technical details of the procedures for calculating TACs before considering their allocation.

3.1.1 Calculation of a Total Allowable Catch (TAC)

Implicit in the calculation of a TAC are criteria which specify some aim of management. These criteria could, for example, reflect a desire for MSY, for a particular target fishing mortality, say $F_{0.1}$ (Boerema and Gulland, 1972) or for a long-term maximization of yield per recruit. Pope (1984) reviews the problems faced by scientists in interpreting ambiguous goals in order to give scientific advice on TACs. Readers are referred to Pope for details, but it should be emphasized that such goals should as far as possible be unambiguous. The main problem is that many management goals do not directly translate into a target fishing mortality rate. Accordingly it is often necessary to interpret the goal in these terms before proceeding with the calculation.

Given some specified goal, the calculation then involves the following procedures. Initially, it is necessary to make some assessment of the abundance and biological structure: e.g., age or length composition of the stock. Such a process can be done directly or indirectly. Direct methods involve, for example, acoustic surveys supplemented by random samples of the size composition of the stock. This is a method favoured for species whose recruitment is highly variable and whose mortality rate is sufficiently high that recruitment forms a significant proportion of the total stock. A variety of small pelagic species - capelin, sardine, anchovy, herring - are assessed in this way.

Indirect assessment of current abundance can be done using the technique of Virtual Population Analysis (VPA) or by means of production models which relate catch rates to the abundance of the resource.

Direct methods are costly, but can provide reasonably accurate assessments of current abundance. Indirect methods are cheap, often relying solely on data collected as a matter of course during fishery monitoring, but are often inaccurate, sometimes grossly so.

It should not be inferred that in all cases direct methods can provide a reasonably accurate estimate of abundance. There are a number of problems of sample design and calibration which (in some cases) render them ineffective. For example, the interpretation of acoustic data on shoals of mixed species is highly ambiguous.

The main problem with indirect techniques is that they rely for estimates of current abundance on a variety of ad hoc methods for calibrating effort efficiency. They are correspondingly inaccurate where effort calibration is difficult. Pope (1979), and Pope and Shepherd (1982) discuss the mathematical details of this process. A second problem is that the calculations can be sensitive to the estimate of the natural mortality rate of the fish stock. In many cases this parameter can only be estimated with considerable uncertainty.

Once an assessment has been made of the abundance of the resource, the calculation of a TAC according to specified criteria is straightforward. Indeed the mathematical apparatus for such calculations has been available for several decades (see Ricker, 1958; Beverton and Holt, 1957).

Pope (1984) considers in some detail the calculation of TACs given a specific goal and an estimate of abundance. He describes a number of problems, all of which point to a substantial level of uncertainty in the calculations. Apart from this conclusion the technical details are inappropriate for consideration in this study. The main problems may be simply stated. If it is possible to obtain estimates of abundance of each age class in the fish stock, the fate of these age classes in the future can be predicted, using a fixed natural mortality rate and some specified level of fishing mortality. Extrapolations concerning the total stock will be subject to error due to the incoming recruitment (which cannot be readily estimated) and that associated with the estimates of current abundance and natural mortality. Where the fish stock has a low total mortality rate (defined as the sum of fishing and natural mortality), these extrapolations will be reasonably accurate as the new recruitment is a small part of the stock. If the species has a high natural mortality, or fishing pressure has made total mortality high, the stock will consist of few age classes and recruitment will be correspondingly important. In such situations predictions will tend to be inaccurate. The corollary of this observation is that high fishing rates can lead to greater unpredictability.

Where these problems are acute, direct estimates of recruitment strength are sometimes made to supplement the indirect estimates of the older post-recruited part of the stock. Examples occur in a number of fisheries for pelagic species. Typical fisheries are those for various herring stocks in the North Atlantic and anchovetas and sardine of the Eastern Pacific.

The procedure for calculating TACs may be illuminated by considering the recent practice of the Advisory Committee for Fisheries Management (ACFM) of the International Council for the Exploration of the Sea (ICES), which provides scientific advice to countries fishing in the North-East Atlantic area. In their reports the ACFM typically shows catches as a function of the fishing mortality that they will impose on the stock. Such a graph can then be used to show how the appropriate management objectives of the administrative body can be achieved (Hoydal, 1984).

In other management bodies, for example, in the International Whaling Commission (IWC), once the status of the stock has been assessed relative to its MSY level, the calculation of a TAC comes automatically from the rules of the New Management Procedure (NMP). In a similar manner, proposals for managing the Californian anchovy assess the relationship of the stock to its optimal sustainable yield, and then assess TACs on the basis of simple rules (McInnis, 1984).

Although simple in concept there are a number of problems associated with these procedures for the calculation of a TAC which are not widely recognized. The most obvious problem is that they rely on a history of accurate data on the age or size composition of the catch, the effort and the catch per unit effort of the various components of the fishery. Such data are often not available on fisheries in developing countries and clearly are not available in newly developing fisheries. However, the most important disadvantage of management based on TACs has become apparent recently. The problem is that the adoption of TAC management has often been accompanied by a marked deterioration in the quality of the data. Under-reporting of catches undermines all the techniques of resource assessment. The scientists are quite unable to perform assessments if data are not available or are unreliable. It is a reflection of the magnitude of this problem that a number of scientific groups have declared themselves unable to calculate TACs on the basis of the data made available to them (Griffith, 1982; Hoydal, 1984).

A less important, but still significant problem involves the allocation of scarce scientific manpower, which is often called upon to make annual assessments of stock status and TACs. Hoydal (1984) reviews current practice of the International Council for the Exploration of the Sea (ICES). He documents an extremely elaborate system of working groups and committees meeting for a significant portion of the year. Clearly such concentration of manpower cannot be done at low cost.

A reasonable question to consider in this context is the potential trade-off between the average level of catch obtained and the precision required of the estimate. For example, if it is required that the TAC should correspond to the level where MSY can be obtained, it will be necessary to monitor continuously the stock abundance and to revise TACs on a regular basis. By contrast, if the management was aiming to catch only some small proportion of the MSY level, the need for monitoring and regular changes in TAC levels is substantially reduced. The trade-off between the level of catch and the costs associated with scientific monitoring have rarely been quantified, but there is clear scope for investigating the possibility for less frequent monitoring.

In multi-species fish communities, the standard methods for assessing stock abundance, fishing mortality and potential yield are all exacerbated. Here, the setting of a global catch level faces the problem that substantial numbers of by-catches and discards occur.

The problem of by-catches has been recognized for some time. In particular, management in the North-West Atlantic, under ICNAF, operated on a whole range of individual TACs, all with separate by-catch regulations. In the ICNAF area these by-catch regulations often meant that the TAC was unattainable, given the selectivity and areas of operation of the fleets (Brown, Brennan and Palmer, 1979). Current regulation of the sprat fishery in the North Sea forbids a by-catch of herring greater than 10% by weight (ICES, 1982). With decreasing sprat and increasing herring this presents problems for fishermen in complying with regulations.

Discards occur when fishermen choose to throw away less valuable fish in order that their quota consists only of the most valuable. Such a problem is not unique to multi-species fisheries, but also occurs in situations where a wide range of age classes of a single species are harvested and larger and older fish are more valuable per unit weight. Indeed legislation to regulate the rate of discarding has some history in the North Atlantic, and sorting machines (which enable small fish to be separated) are banned for certain fisheries.

3.1.2 Allocation of TACs

Without allocation, the tendency for fishing enterprises is to move towards an over-investment in equipment and labour in order that they may increase their share of the common TAC. This has in the past caused severe problems, with a major disruption in the seasonal pattern of a fishery as fishermen rush to obtain their share of the quota. Often vessels increase in size and add engine power both to get more quickly to and from the grounds and to operate with greater fishing power, while there. Allocation can occur between nations and within a nation.

3.1.3 International Allocation of TACs

There are four main types of international allocation: firstly where there is fishing with open access; secondly where there are shared stocks; thirdly where there are anadromous stocks; and fourthly where there is foreign fishing within a national EEZ.

Under the pre-LOS conditions, the open-access fishing was typical; since the LOS and the Declaration of EEZs only a few high seas stocks, such as the tunas, are harvested in this manner.

The European Economic Community is a unique example of a group of nations which have agreed to combine their fishery resources and act as a single State. Having done this they now allocate their common resources among themselves and negotiate as a unit, with other States, concerning shared stocks.

Although there is clear need for there to be some allocation between countries when stocks are shared, it is quite clear that there will be no hard and fast rules for such allocation. When stocks are shared, criteria that have been used in the past have involved the biological characteristics of the shared stock. These include the location of spawning grounds and the migration routes of juvenile and adult fish. In some sense such information can be used as a basis for allocation, although the details clearly involve political negotiations, in which other factors may play a more important role.

Where countries do not have sufficient industrial capacity to land the TAC within their EEZ they may choose to allocate a proportion to foreign vessels.

The allocation of a TAC to foreign vessels when the stock is solely within the jurisdiction of a single coastal State is clearly the right and prerogative of the coastal State. Two decisions are to be made: How much of the TAC is to be declared as surplus to the needs of the coastal State and thus is available for foreign fishermen? How is the total allowable level of foreign fishing to be allocated among various nations? In the past such allocation has been made on the basis of historical performance, i.e., where, when and how often fishing by foreign vesseis had occurred in pre-LOS conditions. More recently the allocation appears to have been made on the basis of the provision of data and cooperation in research and enforcement.

It is often the case that countries will consider the allocation of a TAC to foreign vessels to be of a temporary nature until such time as they are able to build up their own capacity. However, where the resource fluctuates in natural conditions in a substantial manner it can often be economically optimal to choose to develop the fishing industry to a level where the domestic capacity can always be satisfied. The surplus to this capacity is then allocated on a year-to-year basis to foreign fleets. These fleets, given sufficient lead time and a number of different stocks where they have temporary access rights, may find such an arrangement attractive. Beddington and Clark (1983) have investigated in some detail the theoretical basis of policies of this type.

Intra-national Allocation of TAC

When a country is the sole owner of a fish resource, or has agreed in international negotiation to its proportion of a TAC, it faces the problem of allocation of that TAC amongst its national groups. Such allocation can be highly detailed and technical or can be of a general nature. Often the aim will be to improve both the efficiency of individual enterprises or to make the allocation between different groups of fishermen more equitable. The improvement of the efficiency of an individual enterprise is best achieved by the allocation of a proportion of the TAC to that enterprise. Where this occurs there is no incentive for fishermen to over-invest in equipment and labour in the hope of improving on their share of the global TAC. Such allocation, however, conveying as it does, an effective property right to individuals, must be considered in the overall context of the fishery management policy of the country.

Allocation to individual groups of fishermen often can occur on a geographical basis. Thus allocation rights to a quota to artisanal fishermen may best be achieved by dividing up the appropriate TAC amongst different sectors of the coastal population. A similar allocation between industrial and artisanal sections can also be made.

Administration of Catch Limits

A significant problem alluded to above concerns the necessity of enforcing a TAC, both in terms of the information that is collected for scientific purposes and to ensure proper management. The nature of many fisheries means that enforcement of catch limits will often be, if not impossible, on the high seas, extremely expensive. In such situations there are distinctive advantages in monitoring catches and enforcing quotas at the point of first sale. Analogies can be drawn between illegal catches, i.e., greater than the allocation, and the receiving of stolen goods. The buyer of fish from fishermen being clearly in the key position to provide evidence that the fish purchased were not in contravention to regulations. Accordingly an attractive idea is to involve the fish buyer in the enforcement process. This occurs in some Alaskan fisheries (Tillion, 1984).

There are clear interactions between the enforcement of TACs and the collection of accurate data for the purposes of stock assessment. Past failures in the developed world have already been referred to in this context. It is clearly undesirable that regulations put a premium on cheating and that enforcement fails to stop it.

The cost of enforcement needs to be set against the benefits to be obtained by operating a TAC form of regulation. It is apparent that in many developed countries the cost of enforcement is extremely high (Derham, 1984; Schowengerdt, 1984). In a similar manner, developing countries should rightly query the benefit of operating a TAC-based management when they have to face the problem of financing enforcement.

3.2 Indirect methods of controlling fishing effort

Although the most obvious way to control fishing effort is by directly regulating either the catch or the amount of effort, such direct methods of control do have a number of problems. In particular they are difficult and complicated to enforce and hence expensive. Furthermore they are in the words of Caddy (1984b) "information hungry", i.e., for their proper administration they demand considerable amounts of data collection. Accordingly there are attractions in methods which are neither as complicated nor as costly. We now consider such methods.

3.2.1 Closed Seasons

There are effectively two types of closed season; the first one occurs when particular periods of the year are banned for fishing. In such situations it may be possible to protect particular life history stages of a stock, for example juveniles or small fish. The Peruvian anchoveta fishery was normally closed early in the year when small fish (peladilla) were particularly abundant.

Although the closed season can be effective in restricting fishing mortality on particular life history stages, there are considerable problems in using it as a broad measure to control fishing mortality. The reason is that if catch rates are high outside the closed season, the economic characteristics of the industry will lead either to increasing fishing capacity entering the industry or to an expansion of the capacity of the vessels already there. This, if allowed to continue, can lead to increases in fishing mortality up to and beyond those occurring prior to the closed season being instituted.

Closed seasons also can have a disrupting effect on marketing, generating as they do, discontinuities in supply.

The second type of closed season occurs with a natural feed-back generated by the effect that fishing has on the fish stock. In essence the idea is to assess a decline in the catch rate as the season progresses and when some pre-determined catch rate (corresponding to some target level of stock abundance such as a minimum spawning biomass), is reached the season is closed. The underlying ideas behind such a method are those of De Lury (1947) and Leslie (1952). Both methods rely heavily on the direct relationship between catch per unit effort and stock abundance and are correspondingly inappropriate for species where this relationship is weak.

Closed seasons of this type also tend to involve the sort of over-capitalization considered above. Fishermen are tempted by high catch rates at the start of the season to invest heavily in capital equipment to increase their share of the ultimate yield.

3.2.2 Closed Areas

A similar method of regulating fishing effort on particular life history stages of a species is to designate a particular geographical location as a closed area for fishing. A number of examples occur in developed countries, typical is the "Norway pout box" around the Shetland Isles.

Often closed areas may provide shelter from fishing mortality for certain life history stages, but this can well be at the expense of increased fishing effort on other age groups. Accordingly it is necessary to assess the overall effect of such closures on the dynamics of the stock. For example, protection of age groups zero and one may not produce appropriate protection of the spawning stock when fishing mortality rates are high on the other pre-spawning age groups.

In some circumstances, protected areas may be extremely useful in ensuring that, for example, portions of the spawning stock are protected; this ensures an effective escapement with corresponding conservation benefits.

A particular application of closed areas, which has been adopted in a number of developing countries, is that of the "Coastal Belt". The aim of this regulation is to protect artisanal fishermen from competition with trawlers who typically fish well within the normal range of the artisan (Khoo, 1980; Pathansali and Jothy, 1974). Obviously, such regulations depend on the detailed natural history of the stock concerned. It is, for example, quite useless in a situation where fish are first exploited by the industrial fishery offshore, and only then migrate into the coastal belt. Even when this is not the case, there will be a tendency for the fishing effort of the industrial fleet to concentrate on the borders of the coastal zone (Marr, 1982). Close surveillance and enforcement will usually be necessary to make such closures effective.

Comments

One of the attractions of closed seasons and, if they are relatively large, closed areas, is that they are relatively easy to enforce. In particular, aerial surveillance coupled with patrol vessels can prove a cost-effective way of ensuring that these regulations are obeyed (Derham, 1984).

3.2.3 Mesh Regulations

Traditionally one of the main methods for controlling the pattern of fishing mortality is via mesh regulation. The underlying theory has been well understood since Beverton and Holt (1957) and may be simply stated: the large mesh net permits young fish to escape and hence to grow and contribute to the biomass of the fish stock in subsequent years.

One problem of mesh regulations is that in the immediate period following their introduction, catch rates will fall. In essence this means that the fishermen are being expected to make a sacrifice now for future benefit. This may or may not be economically optimal for the fishermen concerned and hence may attract disfavour if it has a net discounted cost to the individual. In such situations it is all too easy for fishermen to bypass such regulations in a number of ways. Correspondingly, if this is the case, enforcement will be difficult and expensive.

The speed with which the benefits of mesh regulation occur depend on the biological characteristics of the species concerned. For long-lived species with a low mortality rate, such benefits will be several years in occurring, for short-lived species benefits can be expected within a few months.

One problem with mesh regulations is that, although the expected benefits are easy to calculate, such benefits in terms of changes in stock size or increased yields to fishermen are extremely difficult to detect. The reason is that natural fluctuations in recruitment far exceed the expected changes in yield and stock size, and hence can mask any benefits. Accordingly it is almost a matter of faith that such benefits occur. The problem of communicating such faith to a fishing community can be difficult. This is particularly important as fishermen have at their disposal a number of ways of circumventing these regulations (Thompson and Ben Yami, 1984).

One area where mesh regulation has been found to be relatively successful is in legislating between the desires of industrial fisheries and those for human consumption. Banning of small mesh nets can effectively close down an industrial fishery. Examples of this are to be found in various areas around the world, but most noticeably in the North Atlantic (Jones, 1984).

In multi-species trawl fisheries typical of the tropics, for example Malaysia, Indonesia and Thailand, there is a major problem with mesh regulations. Trawl fisheries in such areas typically catch a large number of species and each species in terms of the simple Beverton and Holt theory would have an optimum mesh size. Clearly a single mesh size therefore will be sub-optimal for the majority of species. Despite these caveats there are clear advantages in considering the problem of size at first capture for such fisheries. In the Gulf of Thailand there has been a steady increase in the proportion of small fish in the catch and to some extent this could be alleviated by operating trawls with a larger mesh (Pauly, 1979a). It should be noted in conclusion that mixed fisheries in the North Atlantic face similar problems, although the number of species involved is considerably smaller.

3.3 Restrictive licensing

3.3.1 Control of fishing effort by licence control

In theory the direct control of fishing effort or fishing mortality by licence control is an effective way to ensure the conservation of a fish stock. Indeed formal considerations of the dynamics of exploited species lead to the conclusion that there are considerable advantages in controlling the exploitation of renewable resources in this way (Gulland, 1969; Clark, 1977; Beddington and May, 1977). The basic idea is that catch levels change automatically with stock size, when a fixed level of effort is applied. Put more formally, application of a fixed level of effort is believed to lead to a fixed level of fishing mortality. Accordingly, changes in stock abundance produce changes in catch levels. In other words a feedback is established which should ensure that the stock always tends to return towards its equilibrium. This is the theory. The practice is rather different.

One of the main problems is that effort is not the time-invariant, undivided unit of the simple models. Typically the efficiency of fishing enterprises tends to change, improving with better gear and better information. The appropriate efficiency calibrations can only be made post hoc, when catch rates can be compared with different historical levels of stock abundance. Accordingly, in controlling effort, managers are often in the process of attempting to catch up, often unsuccessfully, with the technological development of the fishing fleet. Such considerations are further complicated by the composition of fishing fleets, in which different units are often not comparable, and by by-catches of non-target species.

In many fisheries, especially on shoaling species, the theoretical benefits of effort control are more seriously undermined by the poor relation between catch rates and stock size, i.e., a fixed level of effort does not lead to a fixed level of fishing mortality.

Despite these problems, direct control of effort by licensing can provide a method of controlling the total fishing mortality. As a tool for ensuring conservation of stocks it is likely to be successful only when introduced relatively early in the development of a fishery. Too often, it has been introduced when capacity is already excessive and its conservation value correspondingly slight. Typical examples are reviewed below.

When a decision is made to institute a licensing programme a series of questions are posed to the management. We now proceed to consider these questions.

3.3.2 How many licences?

Typically scientists will have been able to make some approximate calculations of the potential yield of the stock. In a newly developing fishery, such calculations will often rely on some simple rule of thumb such as that proposed by Gulland (1970). This rule states that an approximation to the MSY of the stock is obtained by the formula: $MSY = \frac{1}{2} MB$; where M is the coefficient of natural mortality of the stocks and B its unexploited biomass. This particular formula has been found in general to over-estimate the potential of the stock, but modifications suggested by Beddington and Cooke (1983) enable a rough approximation to be made on the basis of standard survey data.

The manager can then, on the basis of simple catch rates, calculate how many vessels will be needed to take this MSY. At this stage it is going to be of some considerable advantage to assume that the efficiency of the fleet will increase with time. Hence, such calculations should be made conservatively so that the number of vessels required to take the MSY is not over-estimated. Having made this calculation this figure should be an upper level on the number of licences to be issued. The manager may of course chose, for social or economic reasons, to issue far fewer licences.

Complications occur when more than one type of vessel is going to be operating, but their solution is fairly obvious. If maximum catch rates are assumed for each type of vessel, appropriate combinations of licences for different vessel types can be considered, subject to the constraint that the maximum expected catch does not exceed the MSY.

Clearly this upper figure for the number of licences need not be chosen. The manager may seek to establish a smaller number of licences and then as more information accumulates on the fishery and the fish stock, to expand the fishery by increasing the numbers of licences. He may also seek to operate the fishery at a level well below MSY for economic or other reasons. It should perhaps be said that similar calculations will be required if a foreign fleet is to be licensed within the country's EEZ.

Only rarely are restrictive licensing programmes introduced before fleets have grown quite large relative to the available resource. One of those unique circumstances was when licence control was introduced into the South Australian prawn fishery in March 1968, only two months after the first commercial catches were taken. In this case, other fisheries in the same geographical area were heavily over-capitalized and created a sensitivity to the need for cautious growth in fleet size (Bain, 1984). More common are fisheries where many fishermen and fishery administrators agree that reduction in fleet size would be helpful.

In many nations (e.g., Norway, the United States, Canada and Australia), decisions on eligibility for licences result in excessively large fleets. Fleet reduction (buy-back, scrapping) programmes are often aimed in the direction of smaller fleets, but with no specific fleet size in mind. In a few cases, target numbers of vessels are determined based on such considerations as conservation of the fish resources, maintenance of order in fishing operations, the number of fishing units already engaged in the fishery, and managerial and financial aspects (Asada, 1973). Calculations of target numbers for fleet size require, at a minimum, good data on fishing effort and biological stocks, and preferably good data on the economic and social environment of the fishery. When this is not available, as is the case in Malaysia, limitation in fleet size becomes politically nearly impossible (Majid, 1984).

3.3.3 How long will the programme stay in place?

One very special type of licence limitation programme is a moratorium on new entrants. Moratoria have been used when a rapid decline in the fish stock creates a crisis atmosphere which is thought to be only temporary. A moratorium is usually the first phase in a permanent restrictive licensing programme; it is also used as an immediate response to a crisis which is expected to require long-term policy changes, but where no decision has been reached about the long-term policy.

There are sound reasons for use of a moratorium. For example, introducing a permanent programme which is unfamiliar to fishermen is often politically difficult, while it is easy to say that all current fishermen may continue to fish but that those outside the fishery will have to wait a short while. Nonetheless, moratoria often have severe unwanted effects. For example, in the United States, Maine and Massachusetts responded to over-capitalization of their lobster fisheries with attempts at limited entry. In 1975, Maine froze the number of lobster licences and attempted to develop a permanent system for restricting licences. Political feasibility within the State required discrimination against non-residents which, in turn, was not acceptable in federal courts. The matter was then dropped. However, discussions alone have been credited with significantly increasing participation. When discussions ended, participation rates also fell. On a parallel note a moratorium on new lobster licences was passed in Massachusetts in 1975. While the number of licences issued in 1975 was virtually the same as in 1974, the number of licences reporting landings jumped from 876 to 1,201. Fishing effort then increased, with the number of lobster pots fishing, increasing by 50 percent between 1974 and 1977 (Smith, 1978). These numbers illustrate one conclusion reached in many other areas as well - if the only thing done is place a moratorium on the numbers participating in a fishery, the short-run effect will be to increase fishing effort, leading to negative impacts in terms of economic efficiency, resource conservation and, probably, equity.

3.3.4 What kind of licences should be issued?

A wide variety of licensing programmes exists around the world. The variation reflects social, economic, and political environments, as well as the opportunities to harvest various fish species. The precise nature of these influences affects the level of detail of licence criteria. In addition, the larger the number of restrictions in the programme the better able it will be to achieve a number of conservation, economic and equity goals, but the more expensive and time consuming it will be.

The licence limitation programme in Japan, which evolved gradually throughout the twentieth century, provides a good example of a more complex system. It reflects the social, economic, and political factors which, along with the fishery resources available to the island nation, have led to its importance in the harvesting, processing, and consumption of seafood. Early use of licence control was adopted primarily to protect the large number of coastal fishermen using relatively simple fishing techniques from a growing fleet of large, more powerful trawlers. The continuing growth of restrictive licensing was based on such other objectives as the reduction of competition and prevention of disputes between different groups of offshore fishermen, stabilization of fishing conditions, maintenance of profitability, conservation of resources, and prevention of international disputes (Kasahara, 1972).

A complex system of fishing rights and fishing licences is a key part of the Japanese approach to fishery management, perhaps more so than in any other fishing nation in the world. The licensing system controls the activities of each fishery through restrictions on the total number of licences to be issued, size of vessels to be used, area of fishing, method of fishing, and often species to be taken (Kasahara, 1972). The Japanese system also is more sensitive to multiple-purpose and multiple-species fisheries than other nations' programmes. For example, a joint limitation on fishing effort for purse seine fisheries for sardines, mackerels, and horse mackerels is the key regulation on fisheries for stocks which migrate in the same area and appear to be closely related in abundance fluctuations (Asada, 1973). The detailed nature of the licensing programme reflects not only the complexity of the world-wide, intensive exploitation by the Japanese, but also the relatively minor use of other forms of regulation, compared to other major fishing nations.

Other nations tend to follow many of these same principles. For example, Malaysia issues licences which effectively assign certain sizes of vessels to specific areas. The zone from 5 to 12 miles from shore is reserved for owner-operated trawlers and small purse seiners. Waters from 12 to 30 miles from shore are assigned to large trawlers and purse seiners as well as other fishing gears wholly owned and operated by Malaysians. Foreign fishing, including both joint venture and charter can operate inside the EEZ, but must remain more than 30 miles from shore (Majid, 1984).

In Alaska, licences are issued to fishermen which are specific to one species or a closely related group of species, a particular gear type, and an area. If licences had less detail, major shifts in effort could defeat the purposes of regulations. Many Alaska fishermen are highly mobile and quite capable of shifting their activities from one area to a quite distant area. There are obvious economic disadvantages in such restrictive licensing. However, fishermen are able to operate with different gear types or in more than one area by obtaining more than one type of licence. This goes some way towards alleviating these disadvantages.

Great care is often required if restrictive licensing is to stop the increase in effective fishing effort. If vessel licence limitation combined with a fleet reduction programme increases profitability, remaining vessel owners will try to increase their share of the resource by further investment in a larger vessel size or additional gear. If licences are tied to fishermen rather than vessels, the same phenomenon will occur - investment will tend to increase the effective fishing power of each remaining fisherman. Thus "capital stuffing" (the tendency to increase the ratio of capital expenditures to whatever component of effort is limited), "seepage" (the tendency for effective fishing effort to seep back when nominal effort is reduced), and similar terms reflect the theoretical economist's argument. If there are three or more inputs to a productive process, one of which is unpriced (the fish in the sea), and another which is reduced while the value of the product is constant or continues to rise, then profit-maximizing firms will tend to increase their use of one or more of the other inputs.

The tendency for economic efficiency gains from licence limitation to be dissipated over time has been recognized by managers of licence control programmes in many countries. For example, as British Columbia authorities noted the tendency for the restricted number of vessels in salmon fishing to be replaced by larger vessels, restrictions were added requiring ton-for-ton replacement, i.e. to add a new vessel twice as large as older vessels, two vessels would have to be retired rather than just one. Additional restrictions limited the ability of vessel licences to be transferred from one gear type to a different gear type having greater fishing power per unit of size.

Japan also had to respond to vessel owners who tried to increase the size of their vessels in restricted fisheries. Japanese licensing authorities limited this tendency by issuing licences specific to tonnage classes. Not surprisingly, the bulk of vessels in a 20 to 40 ton class tended to be 39.9 ton vessels. At times the tendency to maximize fishing capacity for a given licence-restricted dimension jeopardized the health, safety, and comfort of the crew as when sleeping space was decreased to increase hold space (Keen, 1973). Government accommodations of industry demands for upgrading vessels to accommodate new technology and allow for new fishing technologies tended to increase the effective fishing capacity beyond what otherwise might have been permitted.

To permit changing technologies and fishing opportunities, vessel owners were allowed to replace old vessels with new ones of equal size range or to build new ones of larger size by the "tonnage supplement system" (Asada, 1973). For example, if two 140 ton deep-sea tuna vessels were withdrawn, the owner could licence a 280 ton tuna vessel (actually a slightly larger vessel because eligible tonnages are calculated by the top end of weight ranges). The important point here is that, during good times in fisheries, licensed tonnage traded hands at good prices. For example, supplementary tonnage for high-seas skipjack tuna vessels rose from $100 per ton in 1955 to about $500 per ton in 1959 and approached $1,000 per ton in 1960 (Keen, 1973). Such prices reflect a value to limited licences and suggest that licence restrictions contribute to industry profits.

3.3.5 Who issues the licence?

In some nations, licences must be issued by the level of government responsible for marine fisheries. In others, the choice of administrative agency may be rather flexible. In general, the more issues of high national purpose are involved the closer the jurisdictional choice will be to the national level and the greater the variability in local circumstances the closer the choice will be to the local level.

In Japan, fishing licences are granted either by the Minister of Agriculture and Forestry or by Prefectural Governors. The first licence is awarded for fisheries which the National Government has designated as requiring national control. The reasons for national attention are the large size of vessels employed, the wide area of fishing operations, the existence of international fisheries agreements, and the nature of the fishing grounds (Asada, 1973). The second type of licence can either be for a fishery requiring nationwide coordination, where the Minister fixes the maximum number of vessels to be licenced for each prefecture, or for fisheries which the Prefectural Governors, on their own initiative, regulate in order to coordinate fishing operations at the prefectural level.

Another country where licenses are issued at more than one jurisdictional level is the United States. Most fishing licences are issued by individual States in order to allow maximum responsiveness to variations in local circumstances. However, licences to harvest mid-Atlantic surf clams are issued by the federal government because other approaches to restricting effort to this offshore resource were insufficient and local States had not been able to coordinate licence control on their own.

3.3.6 Who is to be licensed?

In many countries, one of the issues which impedes initial political acceptance of a programme arises from criteria for initial qualification. The larger the number who fear that they, their deckhands, or their children will be excluded, the greater the resistance. On the other hand, the easier it is to get a licence, the less effective a programme will be in reducing excess capacity.

An illustration of a weak approach comes from the United States. A limited licensing programme for salmon in California based initial qualifications on very permissive standards. Basically, a person was eligible if one salmon was landed in any of six base years prior to the programme, or owned a boat under construction during part of the base period, or made a good faith purchase on a vessel intended for salmon fishing. California also included cooperation in landing one salmon as another criterion. Rather than decreasing the licensed fishermen as planned, the number of fishermen participating actually rose in the first year of the programme. Since that time, standards to maintain licences have become far more rigorous at the request of the fishermen.

Most licence control programmes have based initial qualification for licences upon historical landings records. Preference for licensing those who have historically fished is due largely to equity considerations. For example, many fishermen would not think it fair to deprive a life-long fisherman of his occupation while awarding a licence to someone without previous experience.

Historical landings data are sometimes difficult to obtain and to interpret. One issue of interpretation is whether to establish the history solely upon landings of the appropriate species in the specific area, other species in the specific area, or the appropriate species in some larger area. For example, in the British Columbia salmon fishery, the fleet was to be reduced upon introduction of restrictive licensing by limiting ordinary licences to harvesters with a significant involvement in the salmon fishery and phasing small producers out during the next ten years. Later, fishermen with histories of halibut landing, but no recent salmon landings were included in the ordinary licence category. This adjustment was certainly responsive and probably equitable, but it also made fleet reduction more difficult.

Extremely high unemployment, limited other economic prospects, and related social concerns have led to special treatment of aboriginal fishermen in North America (Pearse, 1982) and small-scale coastal artisanal fishermen in Malaysia (Majid, 1984). The decision to give preference to artisanal fishermen sometimes conflicts with a preference for full-time professional fishermen, which is reflected in requirements for significant levels of landings to qualify initially and/or retain a valid licence. The reason is that many artisanal fishermen pursue several occupations in order to survive: they fish a little, farm a little, provide craft products or services to tourists, etc.

In many countries appeals boards or committees are used to determine special cases on the right to receive a licence. In some countries fishermen participate directly on such panels. In other countries fishermen are used only in an advisory manner since judgements are considered more equitable when rendered by a disinterested third party. In either case, judgements on issues such as initial qualifications, conditions on use of a licence, transferability, etc., are often perceived by fishermen to be made equitably. However, equity judgements often depend upon how one defines the groups which are being affected. Public participation is strongly stressed in defining political feasibility.

Several procedures are used to enable individuals to obtain licences after a programme is established. One way is to allow licences to be transferred either freely on the market or through formal government channels. One argument as to why licences should be transferable is that a fisherman who labours long and hard deserves to pass that privilege to other members of his family or to benefit through the sale of the licence. On the other hand, where licences are non-transferable, fleet reduction will take place automatically as licence holders retire, die, or move on to other activities.

Licences in Japan are not granted in perpetuity. However, most fishermen need not worry about losing their licences since the licensing authority, in awarding licences, gives first priority to those already engaged in the fishery in question who provide evidence that they will abide by the laws and regulations concerning fisheries and labour, that their vessels meet necessary technical standards, and that they possess sufficient capital to engage in the fishery. Japan is also one of the few countries which has been able to significantly reduce the size of some of its licensed fleets. However, the major reductions were carried out by placing a high priority in licensing other expanding fisheries first to those vessels and fishermen who were giving up their licences to fisheries with excess capacity. For example, the significant reduction in the size of the East China Sea trawl fishery in the 1950s was made possible through the growth in the tuna longline fishery and conversion of trawlers into salmon catchers (Kasahara, 1973).

3.3.7 Will restrictive licensing cause more administrative and enforcement costs?

Restrictive licensing will be ineffective when fishery data and research results are meager.

For example, implementation of restrictive licensing in Malaysia has been difficult in part due to the lack of good data and in part due to social and political difficulties in acting on the data available. Fishermen sell their fish to a few hundred middlemen with large control over the product. Boats are unloaded at the middlemen's facilities, on the beach, or at sea onto vessels from Singapore. The Government has attempted to centralize landings, but the fishermen ignore the Government's landing facilities because of threats from the middlemen, according to remarks by Ibrahim Mohammed reported in Saila and Roedel (1979). Consequently, what statistics are available are collected by sampling at landing points. Majid (1984) documents a number of other areas where information is either sparse or lacking. Because of this shortage of data, administrators are not able to estimate with confidence the number of licences to be issued by fishery and by area. Neither can they determine the appropriate vessel classification by area, suggest alternative techniques where destructive fishing techniques are to be banned, or develop other measures which they believe to be necessary.

Many nations are impatient with restrictive licensing, expecting high benefits to emerge quickly at low costs. However, well-established licensing programmes have evolved slowly, under trial and error. Early stages of licensing programmes can pose especially difficult enforcement problems. At one time, Japan faced a problem recently of concern to Malaysia (Asada, 1973; Majid, 1984). Namely, there were many illegal, unlicensed boats in certain fisheries and little political support to enforce laws against these boats. In both cases, special exceptions were made to licence the illegal fleets, followed by stronger enforcement programmes against unlicensed vessels after the adjustments to the licensing programme. Therefore, countries adopting new licence limitation programmes should expect some difficulties as a normal outcome of adopting a new administrative approach.

The discussion of restrictive licensing above has been related solely to actions by a nation to its own fishermen. However, many coastal fishing nations also issue a limited number of licences to foreign fishermen operating in the coastal nation's EEZ. The principal rationale is that permits or licences are necessary for foreign vessels if they are to be controlled. Other limitations, such as allocated TACs, cannot be effective if the numbers of foreign vessels are unknown. The presence of unpermitted vessels can only be discovered by vessels or aircraft (Chappel, 1984).

The issuing of a licence to a foreign vessel is often associated with requirements for reports and statistical record-keeping (Bain, 1984; Chappel, 1984). While these data are valuable, a further benefit comes from the incentive to fishermen, domestic as well as foreign, to comply with fishing regulations when violations can lead to loss of a fishing licence (Tillion, 1984). The licence serves as a convenient legal means of stopping the fishery at the appropriate time by simply suspending the licence (Derham, 1984).

3.4 Monetary Measures

Governments collect money from fishermen for many reasons; likewise, fishermen are given money or receive reduced tax obligations, in many ways. While these monetary measures are rarely intended to regulate fishing effort, fishermen are influenced. In this section monetary measures directly affecting fishermen are reviewed. The review does not discuss the very important, but indirect influence of monetary measures directed at fish processors, ports, shipyards, etc. However, any tax which reduces the price paid to fishermen does tend to work like a tax on fishermen; any subsidy, such as one for harbour improvements, which lowers fishermen's costs or makes fishermen more efficient tends to work like a subsidy to fishermen.

3.4.1 **Royalties** (fees, taxes, charges)

Fishermen pay revenues to the governments in numerous ways. Specific payments may be levied in proportion to the quantity or value of the catch, with the charge varying by species or characteristics of the catch. Fees are collected for licensing gear units, vessels, and individual fishermen (Ben-Yami, 1984). Such fees may vary by gear and vessel characteristic, and may differ by area, ethnic group and many other categories as has been mentioned in Section 3.3 above. Fishermen also pay personal income taxes, property taxes to local governments, fuel taxes, other sales taxes, business income taxes, etc. If they violate fishing regulations they also pay fines. In addition to monetary payments, fishermen may make payments in kind such as providing food to government observors going to sea on fishermen's vessels and providing labour to fishery habitat maintenance activities.

Fishery managers often omit taxes when they discuss major fishery management techniques because taxes are usually imposed for some reason other than to regulate fishing effort and tax administration is carried out by other branches of the government. Governments tend to collect revenues based upon whatever equity criteria are appropriate to their nation. One criterion - ability to pay - causes taxes to be proportional to income and/or wealth. This reduces the income which fishermen receive from working and may lead to a change in fishing effort.

A second criterion - the user principle - causes taxes to be proportional to the use of the public resource. Taxing fishermen by a surcharge on berthing fees could create a disincentive for fishermen to bring larger vessels into port. A very unpopular example in the United States is a proposal to charge fishermen a share of Coast Guard expenses for being rescued. On the other hand, fishing groups have, at times, supported certain taxes which lead directly to more benefits to them; e.g., fish habitat improvements and expanded hatchery investments.

Many economists have argued that the introduction of taxes in proportion to fishing effort and/or catch can achieve many management goals more economically than other approaches (McConnell & Norton, 1980). However, as Crutchfield (1979) points out, there are many problems with the use of taxes as a tool to vary fishing effort in the short term.

In fisheries, subject to wide environmental variation, fishery managers may wish to vary catches on fishing effort from year to year. As stocks decline, taxes would have to rise if they are to reduce effort. However, political considerations will make it difficult to increase a fisherman's taxes at exactly the same time that his expected catch has been reduced. Even if tax increases are politically acceptable, the existence of several time lags will reduce their effectiveness. First, there is a legislative administrative time lag associated with any change in taxes. For example, in some parts of the United States, local legislatures are the only bodies permitted to alter tax rates and some legislatures meet only once every two years. This lengthy time lag between public recognition of a need to alter a tax rate and actual implementation of the new tax rate is preceded by a lag between the time something caused fish stocks to decline and the time fishery biologists recognized what was going on, collected appropriate data, analysed the data, and developed an argument sufficiently strong to capture the interest of the politician. There is still another time delay between the time taxes are changed and the time fishermen reduce fishing effort. There are several reasons for this last lag. Some fishermen may take a while to understand what the new tax rates mean, i.e., they may be slow to process the new information. Many more fishermen grasp the implications quickly, but are limited in their ability to respond. Switching fisheries may require investment in fishing gear or even a different vessel; it may also require accumulation of new fishing skills or information on the location of available stocks; all of this takes time. Further, since some fishermen will be more able to switch fisheries than others, some fishermen will suffer more in terms of reduced earnings due to the tax change than others.

While the difficulties in using taxes to adjust fishing effort in the short term reduce the usefulness of this procedure as a management tool, nevertheless it has been used with some success. When a 1979 hurricane made major adjustments in fishing patterns necessary in Cuba, price manipulations were used in concert with spatial and seasonal regulations to reallocate fishing effort among alternative shrimp stocks (Baisre et al, 1984).

Although short-term variations in tax rates to react to crises are therefore not likely to be broadly useful, many countries could set taxes to adjust fishing effort between chronically over-fished stocks and alternative, less heavily fished stocks. This is most likely to happen where fishing effort is drawn into a fully utilized fishery, landing a species whose price is rapidly rising. For example, Pacific salmon has a much higher poundage fee in the United States than any of the Pacific groundfish species.

A second circumstance where fees have increased is when a successful licence limitation programme has increased the earnings of the remaining fishermen (Bain, 1984). Finally, fees charged by a coastal nation to foreign nations fishing in its EEZ have been varied from year to year (Bain, 1984; Jelley, 1983). In certain circumstances, not only does a coastal nation feel less pressure to preserve the historic earnings positions of foreigners, they may even increase the licence fees in order to accelerate the replacement of foreign fishing effort by their own domestic fleets.

In summary, taxes can serve as an excellent tool for collecting part, or all, of the public money needed to maintain, regulate, and enhance fisheries. They can be used to channel fishing effort towards the less heavily utilized fisheries, although enforcement of tax collection will become more costly as taxation schemes become more complex and as fishermen and processors are given greater incentives to cheat. Finally, the use of taxation as a regulating tool is likely to be feasible only when changes are made over a long period of time. Although there are exceptions in the case of taxing foreigners and in unusual domestic circumstances.

Equity effects of taxes

In many nations, tax revenues are less than public expenditures on fishery research, management, and the maintenance of habitat. Some of the reasons for this anomolous situation are the low incomes and political vulnerability of many fishermen, or so it is claimed.

In a number of countries, licence fees and taxes on landed fish have risen recently with the intention of collecting a larger share of the public expenses related to fisheries. This has been especially important where restrictive licensing and/or property rights programmes have improved the economic well-being of fishermen.

The collection of revenue by a coastal nation from a distant-water foreign nation fishing in the coastal nation's EEZ follows two major approaches. Some countries are charging high fees. Other nations keep fees low, but require fishery development assistance and preferential market access for the coastal nation's seafood exports (FAO, 1983).

Effect of taxes on administration and enforcement

The administrative and enforcement costs of monetary measures will vary widely from country to country. These measures are usually added to other similar measures within countries and may impose few additional costs unless used to achieve very specific fishing effort objectives. Since administrative issues with such programmes have been addressed in some depth above, only a few major issues are identified here.

It has been argued that taxes are seldom likely to be used to reduce fishing effort or to channel fishing effort from over-fished resources to less heavily fished stocks. Enforcement of tax programmes aimed at controlling fishing effort are therefore likely to be either ineffective or quite costly, since both fishermen and their buyers may go to some lengths to evade taxes and/or the intended effort control. For example, if one species is taxed more heavily than another, enforcement will require checking on species identification to ensure that sales records are not falsified. This may be particularly difficult when the fish is partially processed in the catching vessel, to either save costs, or improve the quality of the landed product. Other evasive actions include landing fish at times or places where enforcement is less likely and vessel-to-vessel transfer at sea, including transfers between vessels of different regions of a country (when taxes vary within a country) and between vessels from different countries. It should be noted that such problems are similar to those encountered in enforcing quotas.

3.4.2 Financial support programmes

Governments provide financial support to fisheries in numerous ways (Ben-Yami, 1984). The price paid for fish is kept high, quite frequently by restrictions on imported fish, and less often by direct payments to fishermen. At times, fuel costs are subsidized, and/or fuel supplies are made particularly available to fishermen during periods of shortages. While fishing gear and vessel construction may also be subsidized, import restrictions to help domestic shipyards and gear shops may also increase fishermen's costs. Public support is provided for gear research and demonstration programmes which contribute to technical improvements. Low-interest loans may be provided for vessels or working capital. Public expenditures are made for environmental improvement, a factor of great importance for fish stocks spending part or all of their life span in fresh water, estuaries, bays, coral reefs, etc. Fish stocks are enhanced. Significant public investments are made in infrastructure (roads, port facilities, etc.). Scrapping (buy back, buy out) programmes are often supported by public funds to make payments to fishermen willing to leave a fishery. Public expenditures are also made to develop alternative, non-fishing opportunities such as the Malaysian programme to expand agriculture near fishing communities (Majid, 1984). Finally, many countries attempt to stabilize fishermen's incomes which otherwise vary widely from year to year (Brochmann, 1984).

Adverse consequences

Nations tend to achieve many of the objectives just noted for financial support programmes. For example, some coastal nations have developed their own fleets and are reducing subsidies used to bring that infant industry to maturity. However, a number of subsidy programmes have led to undesirable outcomes as well.

In some nations, fishery development programmes although subsidized for good reasons have expanded fishing capacity in fisheries which were already over-capitalized. For example, trawlers built to increase fishing on offshore stocks in Malaysia tended to fish on nearshore stocks (Majid, 1984). Subsidy programmes to increase fishing effort on lightly-exploited resources neglected the multiple-purpose character of most new, large vessels. For example, mid-water trawlers intended to replace foreign fishermen pursuing Pacific whiting (Pacific hake) off the Pacific coast of the United States can only fish for Pacific whiting during parts of the year: other times they catch bottomfish stocks which were already being fully utilized by smaller trawlers.

Subsidy programmes intended to aid low income fisheries or fisheries in low income years have the further result of removing the incentive to move labour and capital resources to the fisheries where then can be most productive and to other sectors of the economy where they could be of more value (Brochmann, 1984a). Once incentives to be productive decline, it is not surprising that an "above average" number of years are seen to result in "below average" income. In Norway subsidy payments to fishermen per man year have increased more rapidly than the rise in wage per man year in the industrial sector over the last decade (Brochmann, 1984).

In summary, financial support programmes can and do play a valuable role in development of fisheries. They are particularly beneficial in the introduction of new technology to increase the health and safety of fishermen as well as to reduce costs and allow fishermen to adapt to new opportunities. They are also useful in contributing to the stabilization of widely fluctuating incomes, facilitating compensation for economic distortions created by government, and achieving equity goals. However, some programmes hamper fishery management, stay in place long after their goal has been achieved, and cause economic distortions of their own.

Economic effects of financial support programmes

Financial support programmes can contribute valuably to economic performance in fisheries in many nations. However, this contribution is often accompanied by undesirable outcomes.

Some subsidy programmes can cause fishermen to use economically inefficient techniques. For example, fuel subsidies produce a tendency to use fuel-intensive, wide-ranging fishing techniques when another technique may have been far more appropriate. Subsidy programmes intended to encourage fishing on lightly-exploited species can often have some impact on expanding fishing on already fully-utilized stocks. Financial support programmes started for good reasons may lead to excess capacity in

a fleet, or remove the natural economic forces which would otherwise cause a decline in fleet capacity. Once such programmes are started, they are difficult to remove. Elimination of subsidies at the time fleets grow too large would mean that you subsidized fishermen when they were in a good economic position and removed the subsidy at the same time that incomes were on the decline. Consequently, initial design should include plans for removal of the subsidy before it has caused excess capacity.

Effect of financial support on administration and enforcement

As indicated, subsidy programmes are subject to a number of distortions. Avoiding those difficulties leads to substantial administrative and enforcement costs. To ensure that loans to develop new fisheries do not lead to further excess capacity in fully-developed fisheries requires both a more complex administration in granting the loan (to ensure money is used as planned) and detailed record-keeping in the management agency to ensure that vessels built on specific loan programmes are not transferred into the over-capitalized fishery. Costs and/or political factors keep such administration from taking place other than in rare instances. Political factors also make it difficult to direct financial support solely to certain groups, i.e., if fishermen in isolated fishing communities get low-interest loans, the loans may also become available more generally (Brochmann, 1984a). These problems are made even worse in developing nations when large lending agencies fail to appreciate some of the special circumstances of the borrowing country (Majid, 1984).

3.5 Property Rights

The regulatory measures discussed above have been used in many fisheries where property rights are weak or absent. Where property rights exist, individual rights holders make their own decisions. Various forms of property rights have evolved over time in these countries to meet the needs of each country. The experience with property rights over access to fish and fishing territory with particular emphasis on experience in Japan, Canada, and New Zealand, where a variety of approaches have proved to be valuable, is reviewed.

3.5.1 Territorial Use Rights

Territorial use rights in fisheries have played important roles in many parts of the world for centuries (Christy, 1982; McGoodwin, 1984; Panayotou, 1984). They have tended to evolve where some group found excluding outsiders and defining rules for allocating access to certain fishery resources worth more than the costs of controlling the exclusive use. Among the many techniques for allocating rights are the exclusive assignment of access to certain areas to individuals, or the taking of turns in fishing a certain area. In addition, indirect methods such as the local administration of regulations concerning closed areas, seasons or gear restrictions have been used (McGoodwin, 1984).

Territorial use rights are commonly administered by local governments with or without the sanction of a national government and are, at times, enforced by extralegal means. Examples of extralegal means are the verbal abuse of outsiders, threatened and actual sabotage of fishing gear used by the outsiders, and even physical violence to the intruders (McGoodwin, 1984).

The establishment of sole ownership by a group can lead to a number of benefits. By excluding "outsiders", the resource can be exploited by a group of fishermen sensitive to the adverse consequences of misuse and having a vested interest in keeping the fishery resources viable over time. Such fishermen are more likely to invest in stock enhancement and community works such as landing sites, artificial reefs, aggregation devices, and aquaculture. The local authority may economize on the use of labour and capital in fishing, particularly when there are other productive activities in the local area such as agriculture. Conflicts among fishermen may be reduced; in some circumstances conflicts between fishermen in adjacent areas may also decline. Finally, more flexible adjustment to changes in technology, markets, resource characteristics and the socio-economic structure of the fishing community may be permitted (Panayotou, 1984).

Several conditions affect the creation and maintenance of territorial use rights. Characteristics of the fish species are quite important; e.g., exclusive control over a certain area is important for sedentary or relatively immobile species such as oysters, for species which can be grown in confined space such as pen-reared salmon, for species attracted to fish attraction devices, and for species which migrate between fresh and salt water. The characteristics of the gear used to capture the fish are also important; relatively immobile gear (e.g., traps and weirs) are more conducive to control over fishing territory than mobile gear. The enforcement of exclusive ownership also requires that boundaries can be defined and defended, that cultural factors support the political and social acceptability of assigning exclusive rights, and that the government has the necessary authority (Christy, 1982).

Historical experience with territorial use rights suggests that they will rise and decline in importance as human and natural circumstances evolve. Many such rights which were viable in early stages of history were weakened, if not dissolved, as human populations grew, new technologies emerged, or species originally harvested for local food use became commercialized (Panayotou, 1984; McGoodwin, 1984). Where such trends have weakened fishing rights, some countries have maintained those rights by granting them legal status. The fishing rights system in Japan is a clear example where territorial fishing rights have been incorporated into national law.

Japan

The fishing rights system in Japan has grown out of early regulation in 18th-century Japan. Feudal lords awarded exclusive fishing rights to certain villages in return for payments of royalties. Over time these rights were modified as a lord would grant a special fishing privilege to an individual or a group in return for a large contribution to his government. The "old fishery law", enacted in 1901, recognized and legalized the rights which had been granted in the feudal system. In addition, new exclusive rights were created in response to fishing opportunities opened up by new technology. After World War II, all fishing rights were cancelled and a new fishing rights system was created to reflect the greater democracy in Japan. Those who lost rights in this reallocation were, however, issued compensatory bonds which could be cashed five years later (Yamamoto, 1984).

The fishing right is a right to fish a defined water area with defined fishing gears. While recognized as a formal property right, it cannot be rented, transferred, or mortgaged. The common fishing right, which corresponds loosely to the exclusive fishing right in the old fishery law is granted only to a fishery cooperative and is accompanied with procedural requirements for coordination within the cooperative (Yamamoto, 1984). Common fishing rights cover littoral fishery resources attached to the sea bottom, small stationary gears operating in waters shallower than 27 metres, and beach seines. Set net fishing rights for larger gear stationed in waters deeper than 27 metres are primarily awarded to cooperatives, but other fishermen with proven capital and experience are also eligible. The third type of right, demarcated fishing right, applies to mariculture in a specific sea area; it also applies in principle to fishery cooperatives.

The fishing rights system, as it originally evolved, was a classical form of territorial use right. As new technology evolved, the fishery commercialized, and population grew, the Japanese have been able to preserve the system by use of laws and administrative regulations. Valuable fisheries which have provided food fish to the populace and maintained secure work places in fishing communities suggest that fishing rights have been very useful.

3.5.2 Allocations of TAC as property rights

In the previous section, we reviewed the sole ownership of a fishing territory as a source of property rights. Earlier in this paper we noted that allocation of catch limits to individuals or specific groups is also an important form of property rights. Two case studies are provided to illustrate the increasing use of property rights to conduct a fishery, and some of the issues which emerge when such allocation occurs.

Canada

Territorial use rights have long existed in Canada. Fixed placement of weirs and traps and extralegal agreements among fishermen concerning where each would tend to fish were widely used in the early history of fishing in Canada. In contrast with Japan, as population growth, technological advance, and rising commercial value brought about forces which weakened property rights, the rights were not supported by law. However, as environmental crises and excessive investment in fishing led to heightened concern about fishery management, Canadians began to experiment with individual enterprise quota systems which is more of a property right to fish than the granting of a fishing area. By 1982 there were at least nine fisheries using some such system on both coasts and in at least one large lake (Doucet, 1984). There are also formal proposals to expand use of quota licences in the near future, particularly on the Atlantic coast (Kirby, 1982; Pearse, 1982). In the following section, we review one individual fisherman's quota programme because it dramatically identifies both the possible gains from this fishery management tool and some of the difficulties in developing individual quota programmes.

The Bay of Fundy herring fishery

The herring fishery in the Bay of Fundy began in 1880 as a weir operation providing fish to a canned sardine operation and evolved to a combination of weirs, fixed and drift gillnets, and purse seines of various sizes providing fish into diverse processing channels a hundred years later (Crouter, 1984). In the mid-1960s a collapse in the Pacific coast herring fishery led to the transfer of large purse seiners to the Atlantic coast. At the same time, European vessels were expanding their harvests on the Georges Bank. As a result of the expanded harvest rates, the Georges Bank herring stocks collapsed and the Bay of Fundy stocks were severely depressed (Crouter, 1984).

Following a government freeze on the numbers of units in the domestic purse seine fleet in 1970, quotas were placed on both the Bay of Fundy and Georges Bank fisheries in 1972. Although the growing domestic fleet capacity made management more difficult, the reasons for adoption of radically different regulation measures in 1976 were related to the economic crisis in the industry (Crouter, 1984). Here shortened seasons in response to expanding fleet capacity had led to soaring costs, declining prices (due in part to lower fish quality), and conflict among the herring fishermen. The Government agreed to grant financial support in 1975 based upon expectations of major changes to follow.

In 1976, herring sales for fish meal production were prohibited, over-the-side sales to Polish factory vessels were permitted, and purse seine vessels were given individual vessel allocations. Many of the fishermen organized themselves into a marketing "club" which controlled their fishing activities by organizing sales. Fishermen were able to fish together and share their catches. Prices were higher (especially to "club" members who were the only ones allowed to sell to Polish vessels), the season was longer and profits improved considerably (Crouter, 1984; Doucet and Iles, 1981). Success and "club" membership both grew in 1977, accompanied by minor changes in individual vessel allocations.

In 1978, 26 vessels left the cooperative association. Their reasons evidently were to receive less direction in marketing and harvesting as well as less internal monitoring (Crouter, 1984). The removal of "club" control required an increased level of government control. In 1980, both catch and price were down sharply, mutual cooperation among fishermen collapsed and government enforcement of vessel quotas proved to be generally unsuccessful. Direct, over-the-side sales for 1981 and 1982 were approved by the government on the basis that fishermen groups once again form an association to control marketing and, hence, fishing activities (Crouter, 1984).

A recent, thorough review of the Canadian Atlantic policy (Kirby, 1982) concludes that the allocation of a TAC has been an appropriate development, but that procedures must be further modified to support other national goals. Specifically, the further expansion of the domestic fish processing industry requires replacement of over-the-side sales to foreign vessels with sales to domestic processors. The current restrictive licensing system is also to be converted to a system of transferable vessel quotas. The over-capitalized fleet is expected to decline in number as the more efficient vessels buy quotas from the less efficient. To accelerate the fleet reduction, a five-year buy-back programme for boat quotas has also been prepared. While Canada is still in a stage of development of this approach to property rights, many Canadians feel they are making good progress (Kirby, 1982; Crouter, 1984).

New Zealand

In the last section, Canadian experience with allocation of TAC among domestic fishermen was used to illustrate a use of property rights receiving increasing examination in developed nations (see, e.g., several of the papers in Pearse, 1979). In this section, the New Zealand experience with the allocation of a TAC among domestic fishermen, foreign fishermen, and joint ventures is reviewed. This is done to illustrate how a programme with similarities to the Canadian experience can be used as a tool for managing fisheries.

Recognizing international equity principles emerging from Law of the Sea negotiations and desiring assistance in fishery development such as improved resource assessment, technology transfer and overseas market access, New Zealand provided for three classes of fishing preference when it established its EEZ in 1978. First preference went to domestic fishermen, second to joint ventures, and third to foreign fishermen. Under this system trawl finfish catch by foreign licensed vessels fell by more than 50 percent between 1975 and 1980, while domestic fishermen investing in larger vessels moved further offshore, and approximately doubled their catch. However, in 1980 the largest share of trawl finfish catch was being taken by the new joint venture fleet.

New Zealand not only determines what share of the total allowable catch is to go to domestic fishermen, joint ventures, and foreign fleets, but the foreign harvest is allocated into TACs for each country and the joint venture harvest is allocated into company quotas. Company quotas proved to greatly enhance the administrative feasibility of regulations. Since New Zealand required all foreign vessels to obtain a licence, make a first port call after entering the EEZ and before fishing, and a second port call before leaving the EEZ, most enforcement could be carried out inexpensively at dockside; at-sea inspections could be held to a minimum.

Joint ventures were viewed in New Zealand as a transitional arrangement. If domestic fishermen cannot fully harvest a resource, foreign vessels should be allowed to do so, perhaps in return for a royalty, trade concession or other consideration. If the domestic fishermen can harvest the resource, they should. Thus while joint ventures were working out as well in New Zealand as in many other countries, a recent initiative has been taken to convert the joint ventures into a more domestic activity. Starting on 1 April 1983, nine of the joint venture companies with a greater than 75% New Zealand shareholding have been allocated varying individual quotas which sum to as much as the total quota for some deep-sea species (Waugh, 1984). Initial quota allocation was based on criteria reflecting known performance, available vessels and onshore processing capabilities. Quotas of some species can be traded between companies to permit adjustment of fishing to meet processing requirements (Waugh, 1984).

In summary, New Zealand has evolved a system of allocating shares of the total allowable catch to specific fishing companies as an approach to the development of their deep-sea fisheries. Foreign equity holdings, advice, and technology transfer are permitted, but only in a context which permits domestic fishery development. For fisheries where joint ventures have not proven to be viable, foreign fisheries continue to remain a significant factor.

4. THE CONTROL OF FISHING EFFORT IN FISHERIES OF DIFFERENT TYPES

Clearly the characteristics of a fishery determine to a considerable extent the possibilities of controlling fishing effort by regulation. In this section we consider six main types of fishery: for small pelagic species, mid-water and demersal trawling for relatively few species, multi-species demersal trawling, for tunas, for sedentary species and for highly vulnerable and andromous species. In characterizing these types of fishery we are conscious that no one fishery will conform exactly to our classification. We hope nevertheless to be able to highlight important differences between the possibilities for managing fisheries of each type.

4.1 Pelagic fisheries

In terms of volume, fisheries for pelagic species are by far the most important in the world. The life span in pelagic species varies considerably; from one or two years in the case of some anchovies to up to twenty years in the case of the Atlanto-Scandian herring. For management purposes, it is best to distinguish between the short lived - anchovies, sardines, sprat, capelin - and the longer lived, such as herrings and mackerels. Many, if not most species have demonstrated dramatic declines in recruitment following or in association with reductions in the spawning stock (Ulltang, 1980). Often, even after fishing has been reduced or stopped, some stocks fail to recover (Daan, 1980). Many stocks also undergo long-term variations in abundance independently of any fishing effect (FAO/IOC, 1983).

Purse-seining and directed mid-water trawling for such species typically show no relationship between catch per unit of effort and stock size (Ulltang, 1975 and 1980). Direct monitoring of stock abundance is best done by acoustic methods. The techniques of virtual population analysis and cohort analysis are quite inadequate for assessing the status of short-lived pelagic species or long-lived species which have been heavily fished (Bailey, 1980; Ulltang, 1980). The reason is that the heavy fishing reduces the size of the older age groups and the stock dynamics are dominated by the younger age groups. The abundance of such age classes cannot be assessed with any real accuracy using VPA or cohort analysis. In short-lived species the level of natural mortality is such that this situation prevails even in the absence of fishing.

Clearly there are significant conservation problems in managing pelagic species. Some of the most dramatic declines in fish stocks have come from pelagic species (Glantz and Thompson, 1981; Zuleta and Serra, 1984). There is therefore a major requirement to ensure that there is some reasonable escapement of the spawning stock.

There are a number of economic and social problems which pelagic fisheries tend to generate. For long-lived pelagic species there is often competition between fisheries for meal and those for human consumption. Meal fisheries typically concentrate on the more abundant younger age classes. Fisheries for human consumption usually have some minimum marketable size. Direct competition between such groups in the absence of regulation will tend to favour the industrial fishery as it is able to exploit a year class before it recruits to the food-fish fishery. Unregulated fisheries of this sort have led to dramatic declines in highly productive stocks. The North Sea herring collapse (Saville and Bailey, 1980) is a well known example; others are documented in a variety of papers in Saville (1980).

Conflict between fisheries using highly mobile gear and fixed gear fisheries are particularly acute in fisheries for pelagic species. As indicated earlier, catch rates of mobile gear are largely independant of the stock size. Catch rates of fixed gear tend to reflect the abundance of the stock more faithfully. Accordingly stock declines will initially have little economic effect on mobile gear operations, while that operating fixed gear will face severe disruption.

Since pelagic species in general are highly mobile, a number of pelagic stocks will be shared between the EEZs of different coastal States. Hence, problems of management are exacerbated by the need for international agreements on regulation.

Over-capitalization in fleets exploiting pelagic species can be particularly pronounced. There are two reasons. The first is that the availability of pelagic species is a seasonal phenomenon and hence there is an incentive to expand capacity to try to ensure a large catch in a limited time. Secondly purse seiner design facilitates the construction of larger vessels with greater capacity. These factors tend to create a need for some regulation of the fleet size and capacity.

Management of short-lived pelagic species by TACs is likely only to be feasible if there is a programme of regular surveys of the stock. Such surveys need to be carried out just before the main fishing periods.

Virtual population analysis and cohort analysis may be used for stock assessment in long-lived species, but have value in setting TACs only if fishing intensity is relatively small. A high level of fishing mortality effectively produces a short-lived species which requires direct methods for assessing abundance.

If recruitment collapses are to be avoided, management goals should include some assurance that the spawning stock is not reduced below a reasonable level. This will require monitoring of both catch and stock abundance. It will be correspondingly expensive, especially if the aim is to obtain as high a yield as possible.

A judicious use of closed areas and seasons may be a good method for reducing fishing mortality on juveniles. Many pelagic species have a marked degree of geographical separation of the young age class at certain times of the year. A number of such measures have been attempted in managing such species in the North Atlantic. Unfortunately they have often been applied too late (Saetersdal, 1980).

Size limits and the use of mesh regulations are alternative methods of reducing mortality on the juveniles and improving the spawning stock. Mesh regulations are likely to be of relatively little use in pelagic fisheries; they are useless with purse seines and even in midwater trawling need to be accompanied by gear restrictions such as a limited time for towing. However, a minimum size limit enforced at landing can alter the fishing pattern in a beneficial way.

Direct control of fishing effort by licensing is unlikely to be successful in controlling the fishing mortality on the stock unless a very conservative policy to the number of licences issued is adopted. The reason is that catch rates in pelagic stocks do not tend to decline with the stock size. This means that in poor years the total catch will not decrease and the stock will tend to be further reduced. Pelagic stocks anyway tend to fluctuate for natural reasons in a marked manner. Hence there is a problem that a period of low stock size which has occurred naturally may be extended by the fishery, with accompanying risks of collapses in recruitment.

There are no particular special factors associated with the licensing of pelagic fleets to control over-capitalization. By contrast fisheries for pelagic species may present administrators with a whole set of problems involving conflict between different sets of fishermen. In general resolution of these conflicts in favour of low capitalized, less mobile groups will tend to have conservation benefits. There are two reasons. Firstly, less mobile gear tends to have a catch rate that is more closely related to stock size than mobile gear. This means that, in poor stock years, catches taken by the less mobile gear will tend to fall. Secondly, the target for the less mobile gear tends to be the older and larger age classes. Unless catch rates on these age groups are very high there is a relatively low risk of a reduction in spawning stock leading to a recruitment collapse.

4.2 Fisheries for demersal and semi-pelagic species in temperate waters

There are a whole set of species in temperate waters which lie on a spectrum from the truly demersal flat fishes to the mid-water semipelagic species such as hakes and whiting. Fisheries for these species are economically important as the species are of high unit value.

In such species there have been few dramatic failures due to a recruitment collapse. Possible exceptions to this are the Arctic cod (Garrod, 1977), the grey Pacific cod (Ketchen, 1961; Westrheim, 1978), and the Georges Bank haddock. Conservation problems are usually associated with what may be termed growth over-fishing or more simply with a fishing mortality well beyond that giving the maximum yield per recruit. Often the fishing operates on younger age classes which, in the absence of this fishing mortality, would increase significantly in biomass in later years. Although recruitment failure has not often been observed, this does not imply that drastic reductions in fishery yields have not occurred. The catch of yellowfin sole in the North-East Pacific was in excess of half a million tons in 1961; in 1981 the catch was 77,000 tons. Yet more drastic is the decline in catch of the Pacific Ocean perch. The 1975 catch was just under half a million tons, it dropped to 13,000 tons in 1979 and the 1981 catch is still only 26,000 tons. These figures are somewhat misleading as peak catches tend to occur as the unexploited biomass is fished down to and beyond the level producing the MSY.

There are few examples of species of this type remaining at low levels of abundance for extended periods in the absence of exploitation. Indeed, most such species appear to respond quickly to decreased exploitation. However, in some of the species and in particular in cods and haddocks the year class strength can vary massively. The ratio of the highest to lowest year class in such species can be of the order of one thousand (Hennemuth et al, 1980). Mortality rates are typically small, and the species are relatively long-lived (Pauly, 1979[a]).

These characteristics can present significant management problems, as the variation in stock size will tend to increase substantially with exploitation. This is because the more exploited the fishery the greater is the proportional contribution of the recruiting year class. Heavily exploited fisheries will tend to be dependent on a few year classes; where recruitment is highly variable, this can present problems, in varying income levels of the fishermen and disruptions to marketing patterns.

Except where the fishery is prosecuted on spawning concentrations, usually catch rates appear to be proportional to abundance. Although there are problems of calibrating increasingly efficient effort, they are relatively straightforward. Hence controls on fishing effort will provide fairly close control of fishing mortality.

Assessment of the stock size and status is relatively straightforward. VPA or cohort analysis can be performed as long as reliable catch at length or age data are available and in most cases such assessments should be reliable. There is a corollary to this observation. If management relies on catch data for making scientific assessments of the status of the stock, it will be necessary to institute a programme to ensure that the data are collected in a reliable manner. This can be expensive. There are two important management problems generally associated wtih fisheries of this type. Fishing tends to occur on smaller individuals unless regulated. The regulation of the size of the catches often results in high discard rates.

The second problem is that there are significant levels of by-catch, in the sense that the target species will rarely be the only species caught. There is a particular tendency for small-sized individuals of a non-target species to be caught and discarded.

Discards also tend to occur even in the absence of minimum size regulations as the market value of species of this sort is usually dependent on size. Large individuals can be considerably more valuable per unit weight than the small (Gates and Norton, 1974), accordingly, there is a tendency for there to be high discard rates of small individuals when hold capacity is under pressure, or when there are quota limits on individual vessels.

Regulation by catch limits: This is the most common method of control of such fisheries in the developed world. The main problem is that under-reporting of catches tends to occur. This presents major assessment problems if the data are unreliable and cohort or VPA analysis are the only methods of assessing the stock size. In the same manner, catch limits in isolation (which are usually enforced as landing limits), even when allocated to individual vessels, will tend to result in a high level of discards. This also can lead to unreliable scientific assessment as well as the obvious economic loss. Unreported by-catches or discarded by-catches pose similar problems.

Such fisheries therefore tend to be managed with a number of different regulations concerning the size of the catch and the level of the by-catch. Mesh regulation is common but can be difficult to enforce. In some cases it may be appropriate to prohibit the manufacture or import of nets below a certain mesh size. Mesh regulations tend to be unpopular with fishermen who claim often that they are irrelevant to their needs. The problem of demonstrating the benefit of such regulation in terms of increased yield to the fishermen has already been discussed. In the North Atlantic, for many years mesh regulation in isolation was the only method of controlling the fisheries. It is probably a useful accompaniment to any control of fisheries of this type but is insufficient by itself to provide adequate protection to the stocks. There is a claim that the more successful fishermen within a group tend to operate with larger mesh nets even in the absence of regulations. Presumably this is done to avoid the trouble and expense of having large numbers of discards.

Seasonal closures often present severe economic problems in that marketing is disrupted. They are not particularly successful in solving management problems unless there is a need for regulating a fishery on spawning shoals for conservation or 'fish quality' reasons.

Closed areas can be used with some success in such fisheries to protect either certain species or size classes. Typically smaller size classes tend to be nearer inshore and closure of these areas can control fishing effort on these groups. A significant problem is that such areas tend to be exploited by the less mobile fishery operators. More mobile gear typically operates further offshore on older individuals. In such fisheries there may therefore be some justification for a preferential treatment of the more mobile gear in any allocation of catch limits or licences.

Over-capacity in fisheries of this sort has been severe (ICNAF, 1968); it has also been treated with subsidies with considerable problems (Brochmann, 1984a).

4.3 Tropical multi-species fisheries

In a number of tropical areas the species composition of the fish catch is highly diverse, typically several tens of species in a single trawl. The management of fisheries on such communities poses rather special problems. A recent symposium (Pauly and Murphy, 1982) is recommended as a comprehensive introduction to the management problems posed by such fisheries.

The first problem is that catch rates on the community can decline substantially with increased effort. In the Gulf of Thailand, where an increase in fishing effort has been accompanied by a research programme, catch rates in research surveys have declined by 80 percent between 1963 and 1975 (Boonyubol and Hongskul, 1978). In other areas less well documented declines in catch rates are believed to have occurred. Pope (1979b) considered the properties of the production model applied to the whole community, and Gulland (1982) reviewing this work indicated that such analysis could be used to determine whether the reduction in effort could lead to a greater yield from the community. However, the main conservation problem is what has been termed by Pauly (1982), ecosystem overfishing. This dramatic name describes the somewhat less dramatic process where the species composition of the community moves from one dominated by larger teleostean fish, to one dominated by smaller fish and invertebrates. This has happened in the Gulf of Thailand, in several areas around Indonesia and off Malaysia (Boonyubol & Hongskul, 1978; Pauly, 1979a; Majid, 1984; Sardjono, 1980). The problem is that this change in composition tends to reduce the value of the catch in that a significantly higher proportion of 'trash fish' are now caught. While in the surveys in the Gulf of Thailand the catch appears to reflect changes in the fish community, this may not be true of commercial catches. This adds to the difficulties of assessment.

Although the problem is easily stated, its solution is not. There is at present no body of theory which will predict the effect of different catch levels on communities of this sort. Pope (1979) attempted to develop extensions of simple production modelling to such communities. It is not clear either whether such approaches are valid or whether they can be applied to data typically collected by fisheries of this sort. Pauly (1979a) reviews the management problems of such systems and proposes a number of interesting hypotheses. He does not develop these hypotheses to a level where they can be used to assess the impact of different catch levels on the community. A number of papers in Pauly and Murphy (1982) review the state of the theoretical art.

Despite this lack of coherent theory, it may reasonably be supposed that somewhat lower catch levels would have a less distorting effect on the community structure. This means that there will be a potential trade-off in the fisheries on these communities, between the catch level and its species or size composition.

A related problem concerns the size composition of the catch and the selection of the gear. An attempt has been made to look at the potential benefits in increased yield that might be expected if mesh regulations were instituted (Jones, 1976). The problem has often been stated, but not solved. Optimum sizes of first capture differ between the different species and hence defining an optimum for the system depends on the relative values of each. Furthermore, such calculations can strictly only validly be made when the species do not interact in a biological way; clearly they do. Despite these problems, there could well be advantages to be gained by altering the mesh size of the fishery. The choice of size would however be largely arbitrary. An additional difficulty is that shrimp are high value, of small size, and apparently benefit from the reduction of other species in these communities.

For all these reasons, regulation of catch levels and mesh size cannot be considered as primary management tools at this stage of knowledge.

The changes in community structure and in the reductions in catch rate have produced very difficult problems of social conflict. The shift towards trash fish is most detrimental to the artisanal fisheries who typically seek fish for food. By contrast the high value of shrimp and the increased proportion of shrimp and squid in catches by offshore trawlers has meant that their operations have suffered less economic hardship than would otherwise have been the case.

Control by licensing has been the measure whereby an attempt has been made by the authorities to restrict the catch level and, it is hoped, the change in composition. The success of such measures cannot easily be assessed at the moment as data have accummulated relatively slowly and measures to restrict the licences have either been relatively unsuccessful or too recent to assess (Majid, 1984). The ban on trawling by Indonesia affords an important opportunity for monitoring its effect on community composition and catch rates.

4.4 Fisheries on sedentary species

Sedentary species such as clams, oysters, crabs and seaweeds, and marginally less sedentary species such as lobsters, reef fish and some crabs, provide rather special management problems. Conservation problems are significant due to the vulnerability of the species; however, recruitment - although variable - does not appear to be related to the adult stock. Recruitment catastrophies are correspondingly not a significant problem. The species are however vulnerable to growth over-fishing and without regulation there is a tendency to substantially reduce the larger specimens until the fishery is concentrating on the smaller and less valuable. Their sedentary nature renders the management of the species by the allocation of property rights an obvious choice. This has often been the manner of management; well-known examples are the Chesapeake Bay oysters (Christy, 1964), lobsters off the coast of Maine (Acheson, 1975), mussel beds in many parts of northern Europe, coral reefs in the South Pacific (Johannes, 1978), and Breton seaweeds. Often such fisheries exist on a small scale, but have nevertheless been economically successful. They have rarely produced conservation problems. Exceptions are where physical damage can be done to the habitat, for example, by fishing for reef fish with dynamite or muro-ami.

Where there have been no property rights, or public pressure has eroded existing rights, management has usually been conducted on the basis of closed seasons and size limits. Such management is highly suitable for crustaceans and successful programmes have been implemented on a variety of crabs, clams, abalone and lobsters (Johannes, 1978).

Often gear regulation can enable effective size limits to be introduced without the special monitoring required to police them. Usually such gear regulations are aimed at ensuring that smaller specimens escape.

Where there is significant sexual dimorphism, some care must be taken in the choice of size limit. In the fishery for Dungeness crab, few females are retained as they only rarely exceed the minimum size.

Although such regulations can and have been successful in solving conservation problems, there are nevertheless significant problems of economic inefficiency where the entry to the fishery is unlimited.

Licence limitation schemes have been tried for abalone in several parts of the world, but other licence limitation examples for such fisheries are rare.

Sedentary species are particularly vulnerable to mobile operations which can threaten the productivity of the resource for local populations. Where highly mobile operations develop for sedentary species some allocation in favour of local communities may become necessary.

4.5 Fisheries on highly vulnerable species

Certain species, because of their life history, are highly vulnerable to fisheries. Where significant over-capacity exists in the fishery, acute conservation problems are presented with extinction of particular stocks being a real possibility. Andromous species such as salmon are often vulnerable in this way as are those species which concentrate in large shoals for spawning, e.g., certain herring. Some marine mammals, which at breeding times are readily accessible: humpback whales, right whales and fur seals, are similarly vulnerable. In fish stocks the main conservation problem is thus to ensure adequate escapement from the fishery.

The main method for managing such fisheries is by catch limits. Because of the vulnerability of the species, the catch limits are usually accompanied by a whole plethora of other regulations aimed at achieving some escapement. The fisheries on such species are usually concentrated in short seasons with mesh size, minimum size of fish and restricted gear and area regulations.

The allocation of the catch to competing units in the fishery tends to be done in a variety of ad hoc ways. Where a proportion of the TAC is allocated to a small group of vessels, some over-capitalization appears to occur. However, this is minor when compared to fisheries in which the fixed escapement policy is followed, but the catch is unallocated. In some of the fisheries for herring roe the entire TAC may be taken within a few minutes. Crutchfield and Pontecorvo (1969) noted that the extent of over-capitalization in one Alaska salmon fishery was such that the catch by drift gillnet vessels in Bristol Bay in the late 1950s could be taken by around one-sixth of the gear.

The allocation of property rights in such fisheries has tended to be eroded in the past by their very success. In the early history of salmon fishing in North America a number of property rights were adopted on salmon rivers. These generated such large economic rents that the result was an erosion of these rights by public pressure.

A somewhat different picture occurs for salmon fisheries in the United Kingdom. Property rights to salmon fisheries on rivers have tended to be eroded by the migratory nature of the species. Fisheries now exist on the high seas and in the estuaries as well as in the rivers.

In summary, the management of these highly vulnerable species is probably best achieved by aiming for constant escapement and managing for this where possible, by catch limits. Where catch limits are used, they need to be allocated preferably as a proportion of the available TAC. There is something to be said, in allocating these rights, for ensuring that individual profitability is not excessively high. Such methods could include monetary measures.

Where catch limits cannot be used, it will be necessary to operate some closed season or area to ensure the escapement of a reasonable size of the adult stock. Such methods are best operated with some form of restricted entry or control of effort.

4.6 Tuna fisheries

The tunas are conventionally considered as being highly migratory, but there is a whole range of behaviours from the relatively stable populations of tongol in the Strait of Malacca, through Pacific yellowfin which typically move around 5-600 miles to the trans-oceanic bluefin and albaccre. However, most tunas occur in more than one country's EEZ and typically need to be managed by international agreements.

There is little evidence of declines in recruitment with stock size for most tunas, although there is some concern about bluefin. For some species there are conservation problems due to 'growth over-fishing', but the main management problems are those of over-capacity and the conflict between different user groups.

Monitoring the abundance of tunas is difficult. Acoustic methods are inappropriate, and although catch per unit effort, particularly of long-liners, appears to be related to stock size, the CPUE is highly variable making effort related analyses difficult. There are two main problems involved: the tuna appear to aggregate significantly on oceanographic features as well as on debris and around sea mammals (especially porpoise). This aggregation can lead to a weak relationship between CPUE and abundance (Clark and Mangel, 1979). The other problem is that different components of the fishery operate on different components of the population; long liners tend to catch the larger animals, surface fishing gear (e.g., pole and line) mostly juveniles. Purse-seiners can catch a range of sizes, depending on the mode of operation, such as by setting on porpoise schools or fish attraction devices. The problems of the inter-calibration of effort are correspondingly difficult.

The different size specific preferences of the fisheries present significant management problems, much in the way that meal and human consumption fisheries pose problems in the fisheries for pelagic species. Accordingly, managers will often be faced with significant allocation problems.

This is exacerbated by the fact that vessel catch rates are highly sensitive to the presence of other vessels. This decline in catch rates with increasing effort has resulted in some cases of gross over-capitalization.

Management of tuna by catch limits does seem to be possible, but the fine-tuning of the catch limits to approach the optimum level will require a high level of data collection. Without allocation of these catch limits the increase in fishing capacity is likely to be severe.

Where catch limits are not feasible, due perhaps to the cost of monitoring, the regulation by licensing or effort control can be attempted. As indicated earlier, such licence programmes are probably best achieved if applied in a conservative way. The potential for increasing effort efficiency on a fish species with such a highly developed behavioural pattern is significant. For much the same reasons it may be necessary to bring in gear restrictions or define licences on gear types.

Technical innovation can present mixed blessings in such fisheries if allowed to go unchecked. The recent development of fish attraction devices have been successful, but it has already been necessary to limit their use, e.g., by legislating that they must not be in eyesight of each other. Alternatives applicable in the Maldives, Samoa and the Philippines suggest a minimum distance apart for such devices.

The most well known by-catch problem in tuna fisheries has been the catch of porpoise associated with purse seine operation in the Eastern Tropical Pacific. This problem has been much reduced recently by changes in operational techniques. However, there are still by-catch problems. A particular complication in the mixed species catch of the long liners which can effectively stop the use of CPUE as an index of stock abundance. By-catches of other pelagic species are often associated with tuna catches. They can be of significant economic importance, e.g., in the Payao (fish attraction) operations in the Philippines (White & Yesaki, 1982). In addition there can be a significant problem of discarding of small fish including juvenile tuna by the purse seine high seas operation, especially when catch quotas or by-catch regulations are in force.

5. CONCLUSIONS

To the reader this report may seem to catalogue disaster rather than success, problems rather than solutions. To a considerable extent this reflects the situation of fisheries management today. Yet fisheries management, as we have indicated, is essential, if fisheries are to be a continuing source of benefit - providing food and secure work places in coastal communities as well as a substantial contribution to economic welfare. A central motive behind the theme of this paper has been to indicate that, in managing fisheries, developed countries have made and indeed are making mistakes. In part this reflects the problems of the previous international ocean regime. Developing countries, particularly those with developing fisheries, may find it valuable to learn by these mistakes, rather than to adopt the management practices of the developed world. A number of techniques for controlling fishing effort have been catalogued in this paper and their successes, as well as the more numerous failures, can be guides for improved management.

The central message is that there is no single way of regulating fisheries. Successful programmes of fisheries management will involve a mix of regulatory and other devices. However, there is no point in seeking for a mixture which will provide some perfect solution for all time. Economic and social situations develop, the behaviour of the fish resources of the oceans are variable and to a considerable extent unpredictable, and hence management measures will have to alter with changing circumstances. It is therefore essential to recognize that management must be flexible, new measures to regulate effort may need to be introduced and other ones abandoned. The management scheme that is designed to last for ever will fail, perhaps as badly as the absence of management. This flexibility will be greatly facilitated if fishermen and others engaged in the fishing industry can be involved in the management process. Where measures are either misunderstood or are unpopular with industry, they will be difficult and costly to enforce.

It is also important to recognize the limitations of the science of fisheries. For the foreseeable future the detailed behaviour of fish stocks will be largely unpredictable. This is not to say that the science is useless, rather that it has unavoidable limitations. The same considerations apply to monitoring. A recognition of these limitations is essential for proper management. However, there are useful distinctions that can be made, different types of fisheries are predictable to different degrees, they will therefore need monitoring to different degrees and their management will need to be different.

For certain fisheries a steady state picture of the fish resource and the fishery upon it will be useful for management. In other situations it will be grossly misleading. In the same way, it may be concluded that the economic understanding of fisheries has failed to properly identify the consequence of risk in unpredictable or fluctuating fisheries. As a result, the economic distortions created by subsidies and other financial assistance have exacerbated instability in fisheries instead of designing programmes that can adjust to risk as can be found in agricultural programmes. In addition it appears that the equity considerations for which fishery administrators must react to are not clearly specified, and in fact inadequate attention has been given to the means of achieving such equity changes. Finally it may be said that from the tone of the Consultation, the usefulness of convening a forum of varying fisheries specialists was most appropriate. Given the frustration in seeking appropriate management techniques, it may be hoped that discussions will continue.

In the previous section, we have tried to describe some of the main types of fishery, the special problems they pose and the sorts of management measures that are appropriate to them.

These differences in resource type are complemented by differences in the social structure and economies from country to country. The implication is that each fishery will have special circumstances which will require different regulatory measures to different degrees. The only certainty is that these circumstances will change and new measures will be needed.

One of the most important sources of change will be development, but often indiscriminate actions to encourage development have unfortunate effects on the management of the fishery. This implies that fishery development and management will be more successful if they are integrated, whether within a country or within an international agency.

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